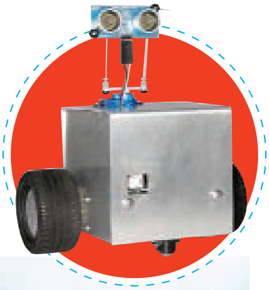
Make:

technology on your time

Build Makey the Robot!
page 76 »



FLYING DRONES »

Build the world's cheapest, funnest, most hackable autopilot.

BY CHRIS ANDERSON

ROBOTS, ROVERS, AND DRONES

STARTING ON PAGE 45 »

PLUS:

» SERVO PRIMER
Learn the basics of servomotors

» PLYWOOD RECLINER
Make your own lounge chair

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MGM
Let your geek shine.
Meet Vanessa Carpenter and Dzl Møbius, SparkFun customers and developers of the Critical Corset. Using a heart rate monitor, an Arduino, and a cleverly hidden air pump system, Vanessa and Diesel designed a corset that explores the rules of attraction. As the user's heart rate increases, the corset gently tightens, creating a more confident posture.
Whether you need a heart rate monitor or just a handful of LEDs, the tools are out there. Create a project you'll love, and let your geek shine too.
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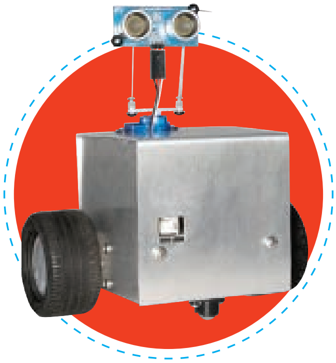
For more info on Vanessa and Diesel's project visit www.illutron.dk.

BY MARK FRAUENFELDER

Surprising Robots



Don't get me wrong — I enjoy the spectacle of a noisy, violent robot war as much as the next person. I love it when sparks fly and screaming circular blades tear into the metal hide of smoke-belching battle bots. It's thrilling to watch one bot ram another and send it flying into the bulletproof plexiglass separating the spectators from the combat arena.

But as much as I like battle bots, and as much as I admire the clever and resourceful enthusiasts who make them, I don't consider these machines to be true robots. Like many crawling and rolling mechanical critters given the label "robot," battle bots are really just remote control vehicles, albeit armored and weaponized ones.

To me, a real robot is one that can "think" for itself, to have a degree of autonomy. In fact, the first use of robot was in a 1921 play by Karel Čapek called *R.U.R.* (*Rossum's Universal Robots*) that featured intelligent androids nearly indistinguishable from human beings.

What does it mean to say a machine is autonomous? I can't think of a better explanation than the one offered by W. Grey Walter, the colorful robot pioneer of the mid-20th century. In his 1953 book, *The Living Brain*, Walter wrote that in order for a machine to demonstrate a "fair imitation" of cerebral activity it must have "some measure" of the following attributes: "exploration, curiosity, free-will in the sense of unpredictability, goal-seeking, self-regulation, avoidance of dilemmas, foresight, memory, learning, forgetting, association of ideas, form recognition, and the elements of social accommodation." Simply put, a machine that behaves this way is surprising, fascinating, and a terrific challenge to build.

It was especially terrific in Walter's day, given the level of electronics technology he had to work with, but that didn't stop him from designing and building electromechanical "turtles" with two "brain cells" that exhibited at least a few of the above attributes. In this volume of MAKE, senior editor Gareth Branwyn reveals the little-known true story of Walter and his robotic turtles.

Walter's dream lives on today, more than 50 years later. Our own MAKE intern Kris Magri designed and built an autonomous robot that could be considered the great-grandchild of Walter's turtles. Her article shows you how to build a Makey of your own that will follow you around the room.

Build a Makey the Robot of your own that will follow you around the room.

Not all autonomous robots are wheeled or legged. Some fly. Our cover story, by *Wired* editor-in-chief Chris Anderson, explains how he and his fellow drone enthusiasts have developed inexpensive autopilots for remote control planes. I witnessed history in the making in April when Anderson's flying drone won the first Autonomous Vehicle Competition in Boulder, Colo. My account of the event is also in this issue.

But this issue of MAKE has more than just robots. We've got a fire piston, a speed vest, a servo primer, and a boombox made from paper cups. If you want to read this issue in style, why not first build the Rok-Bak recliner, designed by Larry Cotton. I had the opportunity to give this comfortable plywood chair a test drive at this year's Maker Faire in San Mateo, and the only thing that could coax me out of it was the lure of a cup of John Park's vacuum-made Florence Siphon coffee (which he presented in MAKE, Volume 17).

Here's hoping your fall is filled with the sweet sounds of making.

Mark Frauenfelder is editor-in-chief of MAKE.

Making Your Way in an Uncertain Economy

"We have chosen not to participate in the current recession."
Glen Kadelbach, GR Kreations
www.grkreations.com

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

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

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Volume 19

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Make: ROBOTS

ON THE COVER: The ArduPilot converts R/C planes to drones. Jordi Muñoz demostrates a successful takeoff. Photograph by Noah Webb. Styled by Sam Murphy. Makey photographed by Sam Murphy.

Columns

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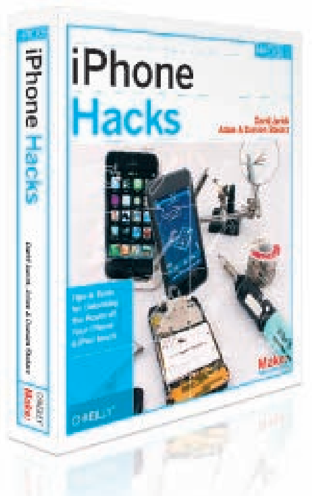
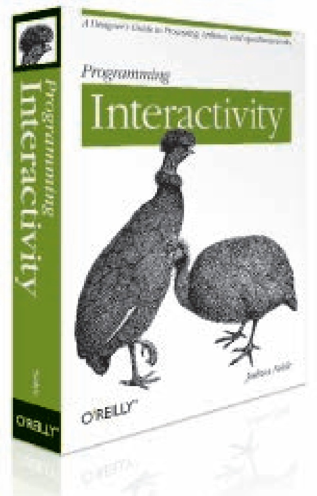
Game on.

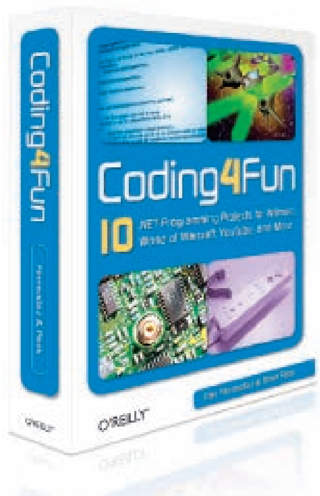
Learn how to use simple programming to make your own fun.



iPhone Hacks
Offers tips and techniques to create innovative applications for both the iPhone and iPod touch. Find and unleash little-known features.



Programming Interactivity
Explains programming and electrical engineering basics, and introduces three free tools for artists and designers: Processing, Arduino, and OpenFrameworks.



Coding4Fun
Helps you tackle cool software and hardware projects using a range of free Microsoft software.

Get your iPhone to perform in ways that Apple didn't intend. Build an Xbox 360 game. Create rich interactive experiences with your artwork and designs. With these new books from O'Reilly, you'll learn how simple code can take your projects to another level of creativity, whether you're building, hacking, or designing.

If you love to tinker, but don't have the time or inclination to figure it all out, these hands-on, practical books are just the ticket.

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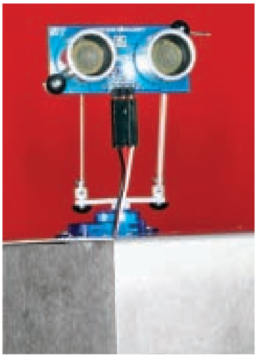
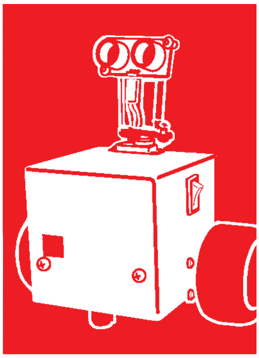
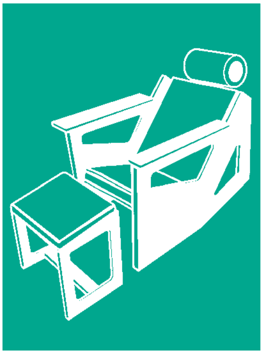
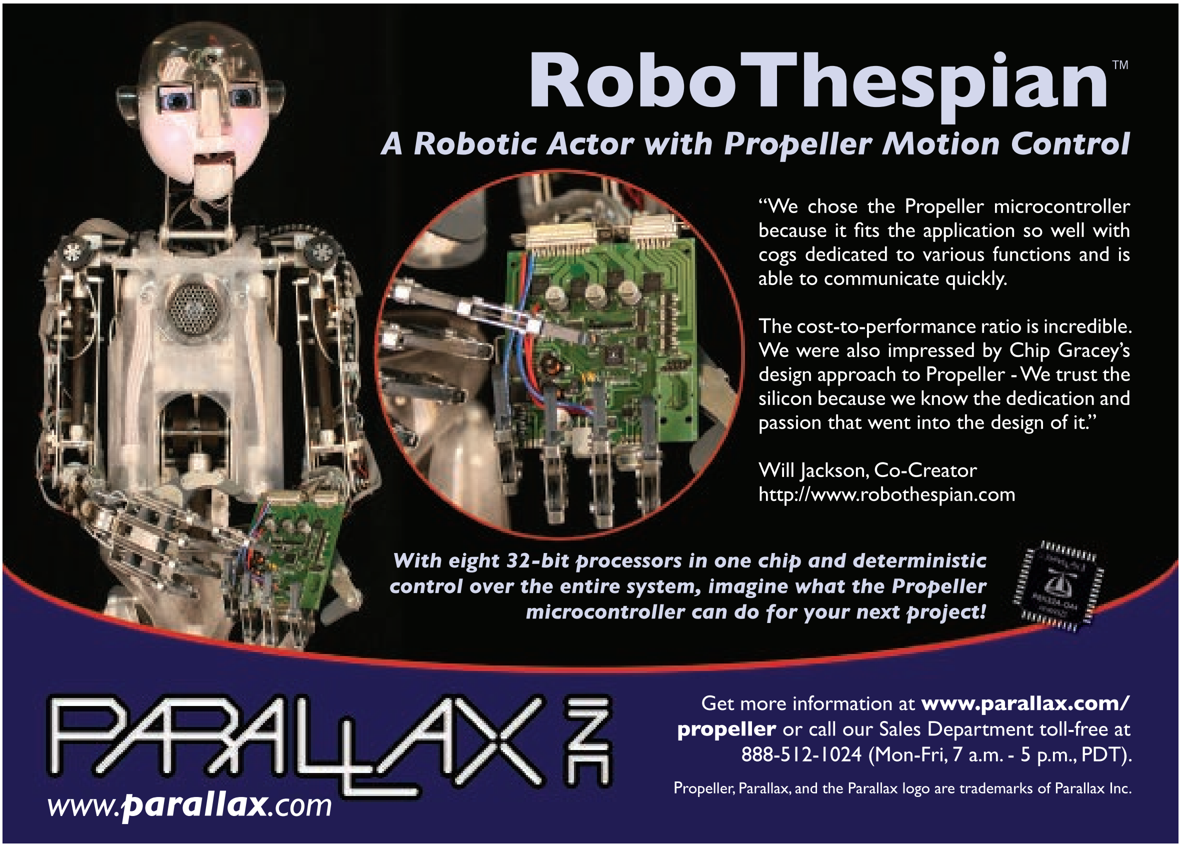
Make: Projects








RoboThespian™
A Robotic Actor with Propeller Motion Control
"We chose the Propeller microcontroller because it fits the application so well with cogs dedicated to various functions and is able to communicate quickly.
The cost-to-performance ratio is incredible. We were also impressed by Chip Gracey's design approach to Propeller - We trust the silicon because we know the dedication and passion that went into the design of it."
Will Jackson, Co-Creator
http://www.robothespian.com
With eight 32-bit processors in one chip and deterministic control over the entire system, imagine what the Propeller microcontroller can do for your next project!
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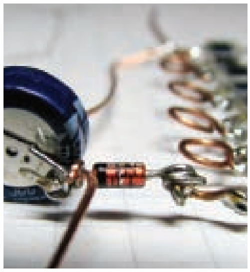
WATER BUG: Seasickness inspired Ugo Conti's wave adaptive boat.

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



> **"The person who doesn't make mistakes is unlikely to make anything."**
> *—Paul Arden*

Make: technology on your time

EDITOR AND PUBLISHER
Dale Dougherty
dale@oreilly.com

EDITOR-IN-CHIEF
Mark Frauenfelder
markf@oreilly.com

MANAGING EDITOR
Shawn Connally
shawn@oreilly.com

ASSOCIATE MANAGING EDITOR
Goli Mohammadi

PROJECTS EDITOR
Paul Spinrad
pspinrad@makezine.com

SENIOR EDITORS
Phillip Torrone
pt@makezine.com
Gareth Branwyn
gareth@makezine.com

COPY CHIEF
Keith Hammond

STAFF EDITOR
Arwen O'Reilly Griffith

EDITORIAL ASSISTANT
Laura Cochrane

EDITOR AT LARGE
David Pescovitz

CREATIVE DIRECTOR
Daniel Carter
dcarter@oreilly.com

DESIGNER
Katie Wilson

PRODUCTION DESIGNER
Gerry Arrington

PHOTO EDITOR
Sam Murphy
smurphy@oreilly.com

ONLINE MANAGER
Tatia Wieland-Garcia

ASSOCIATE PUBLISHER
Dan Woods
dan@oreilly.com

CIRCULATION DIRECTOR
Heather Harmon

MARKETING & EVENTS MANAGER
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Tim O'Reilly, CEO
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For advertising inquiries, contact:
Katie Dougherty, 707-827-7272, katie@oreilly.com

For event inquiries, contact:
Sherry Huss, 707-827-7074, sherry@oreilly.com

Customer Service cs@readerservices.makezine.com
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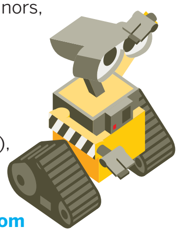
Contributing Artists: Roy Doty, Nick Dragotta, Nathan Garcia, Julian Honoré, Timmy Kucynda, Kate Lacey, Tim Lillis, Rob Nance, Nik Schulz, Damien Scogin, Jen Siska, Robyn Twomey, Noah Webb

Contributing Writers: Chris Anderson, Tim Anderson, Ithai Benjamin, Ed Bringas, Josh Cardenas, Andrew Carrell, Graham Cattley, Abe Connally, Larry Cotton, Brian Dereu, Cory Doctorow, Robert L. Doerr, George Dyson, Julie A. Finn, Saul Griffith, Mykle Hansen, Conrad Hopkins, Lisa Katayama, Laura Kiniry, Tod E. Kurt, Todd Lappin, Norene Leddy, Tim Lillis, Kris Magri, Pete Marchetto, Don McLane, Matthew T. Miller, Forrest M. Mims III, Josie Moores, Johana Moscoso, Steve Norris, Mike Outmesguine, Tom Parker, Bob Parks, Michael H. Pryor, Sean Michael Ragan, Donald Simanek, Carla Sinclair, Bruce Stewart, Jeanne Storck, Vikram Tank, Brent Teal, Cy Tymony, Marc de Vinck, Thomas Walker Wilson, Edwin Wise, Lee D. Zlotoff

Online Contributors: Gareth Branwyn, Chris Connors, Collin Cunningham, Kip Kedersha, John Park, Sean Michael Ragan, Becky Stern, Marc de Vinck

Interns: Eric Chu (engr.), Peter Horvath (online), Steven Lemos (engr.), Kris Magri (engr.), Lindsey North (projects), Meara O'Reilly (projects), Ed Troxell (photo)



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nerds are for dorks
GEEKS
ARE 4-EVER
hacker instead of slacker
Alpha Geek, Turbo Nerd, Proto-hacker
I'M NOT ABOUT
TO TEST MY
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most alive when
LIFE
24/7
I'm playing in the sandbox
Network guru. CGI characters
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Bang the board beige toaster
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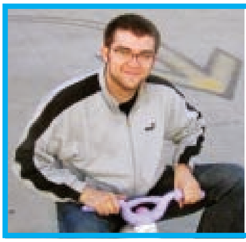
FONT ISSUES DUST BUNNIES
BYTE ME

Contributors

Chris Anderson (*A Drone of Your Own*) is a self-described "suit with an inner geek" who failed out of college, spent his twenties as a bike messenger/punk musician, went back to college to become a physicist, and ended up a magazine editor (*Wired*). He lives in Berkeley, Calif., with his superhero wife and their five kids, ranging in age from 1 to 12. His favorite tools are a fine pair of reversible wire stripper/clippers and a good soldering iron. He enjoys making LEDs blink.

Todd Lappin (*Kustom Tonkas*) lives in San Francisco, where he works as a product strategist and editor to help clients create branded media experiences that delight audiences and deliver strategic results. On the side, Todd is the creator of Telstar Logistics (telstarlogistics.com), a fictitious transportation conglomerate that provides valuable camouflage for his urban exploration and industrial photography adventures.



Steven Lemos (MAKE intern) is a 22-year-old mechanical engineering student. Being a physics nerd, he loves figuring out how things work and sharing his thoughts on the matter. In his spare time, he enjoys the relaxation and quality of slow cooking, and the adventure of kiteboarding and power kiting. Steven is currently rebuilding a BMW E30 to restore all its original glory and more, and he's also building an R/C hovercraft from scratch. He tries to learn something new each day, whether it's about himself or the world around him.

Rob Nance (*Make: Mech* illustration) is a cartoonist/illustrator living in partly sunny Tacoma, Wash., with his beautiful wife, Alison, their adorable daughter Sophia Marie, and their newborn daughter Mei. The two books he would take with him to a desert island are *Mickey and the Gang: Classic Stories in Verse*, which has beautiful 1950s-era illustrations by Tom Wood, and *Hayao Miyazaki's Daydream Data Notes*, which is a collection of mechanical illustrations/comics Miyazaki did for *Model Graphix* magazine.

When not working as a 3D artist at ImageMovers Digital, **Josh Cardenas** (*MIDI Camera Control*) dabbles in guerrilla computer graphics, over-elaborate holiday displays, and absurd multimedia performance and control systems. He spends way too much time thinking about robots. Josh lives in the San Francisco Bay Area with his very awesome wife, Jennifer, his very small orange cat, Zoe, and his very large orange dog, Rory — all of whom are not nearly as fond of robots as he, but do a good job of putting up with them.

Tod E. Kurt (*Servomotors Primer*) started electronics tinkering at age 10; a year later he was merging a Big Trak, an R/C car, and a chemistry set box into an upright programmable robot. Now in the "lab" (converted garage) behind his house in Pasadena, Calif., he designs intelligent objects for the home as part of ThingM (a ubiquitous computing design studio), teaches classes on Arduino, and works with artists to add technology to their pieces. Previously he worked for many years on the web, and before that he worked on the hardware and software for robotic camera systems that went to Mars.

Tales of DTV antennae, fine print, energy ideas, and love for Roy Doty.

Thank you for publishing the illustrations of Roy Doty in your "Aha! Puzzle This!" features. Having grown up on his "Wordless Workshop" strips (which I would love to see reprinted), I think his appearance in MAKE is a bit like carrying the DIY torch from the heydays of *Popular Science*. Please forward my best wishes to him.

—Steven F. Scharff, Henderson, Nev.

I recently dumped DirecTV and ordered two of the government-sponsored digital converter boxes after looking them up on consumerreports.org. I bought the best ones they rated (cost for the two, after the two $40 coupons, totaled about $25).

Well, then I needed a DTV antenna, needless to say. I went back to *Consumer Reports*, and the very first thing in the list of antennas was a do-it-yourself video (with downloadable PDF instructions) on how to make your own DTV antenna, from MAKE magazine (makezine.com/go/dtv). For what little it cost, I figured, what the heck, I'll give it a try!

I managed to complete the job yesterday and get both of my sets hooked up and auto-scanned with the new converter boxes, and I am truly amazed at the results! My neighbor used to work for a company that installs antennas and he said he'd never seen a clearer picture with any other antenna! It may not be the prettiest thing on the block, but, hey, it works just great! Who would have thought a few coat hangers, a piece of wood, some screws, washers, and a simple 75–300ohm converter would produce such a quality picture! My hat's off to you guys!

—Dave Westbrook, Hazelwood, Mo.

I have always thought the world of energy production took a wrong turn just after Benjamin Franklin — why aren't we capturing electrical energy from clouds, as he did? We could have balloons, kites, or tall towers, and sort of "scrape" the electrons off clouds and store them in Leyden jars for later use.

Along the same lines, you could make wind-powered generators, like hooking the Wimshurst generator [*from MAKE, Volume 17*] to a wind-powered crank. More simple, perhaps, would be a wind-powered crank shaft that spun or pulled lambswool-covered pads through or over PVC pipes to generate a charge. Even if these generators only produce sparks, they could at least purify water by generating ozone, or they could be used in electrolysis of seawater to generate hydrogen to power vehicles, or, getting more exotic, in electrolysis of water (and sodium hydroxide) to make deuterium, which has many other uses. Getting a bit off the deep end, perhaps it could be used in room-temperature fusion (which I think could be greatly improved by adding sonoluminescence-producing loudspeakers to the containers of deuterium-rich water along with the palladium electrodes).

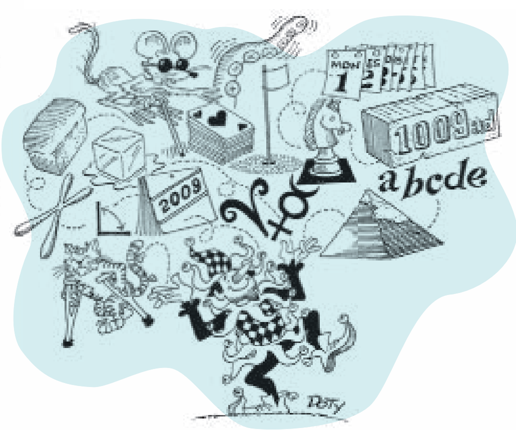
I can see where scientists or scientist wannabes can be thought of as cranks, because there isn't a great distance between nutty ideas and genius. Martin Fleischmann has been ridden out of the United States on a rail, so to speak, but now his ideas seem to be gaining more acceptance at places like SRI and the Navy, where they have begun working with room-temperature fusion (or, what did they call it on *60 Minutes*? — "nuclear effect").

Two other ideas I had were running electric current through steel mesh structures in seawater to cause accretion of calcium carbonate to build piers and buildings and so on (I think this has actually been done by someone else).

The other is to bubble the combustion gases from coal-burning plants through containers of algae to scrub the CO_2 from the gases to create biomass (and reduce "greenhouse gas" emissions). If nothing else, hot gases and even effluent going to cooling towers could either be used to heat greenhouses where crops are raised, or could be directed through towers with vanes that direct cooling winds in a vortex to spin electric generators.

Just some crazy ideas, but I think they might really work. Wonderful magazine, by the way.

—Dan Chase, Midland, Mich.



I am an emeritus professor of mathematics at the University of Wisconsin (and a maker!). My research has largely focused on the thermodynamics and mechanics of heat engines. Stirling engines have been at the heart of all this work. They are of both theoretical and practical importance — and are fun to make! So your recent article in MAKE, Volume 17, "Teacup Stirling Engine," caught my attention.

Although the basic Stirling principle goes back nearly 200 years, the appearance of Stirling engines capable of running on low-temperature heat sources (like a cup of hot tea) occurred only within the last 26 years. I was privileged to work on the development of these engines, producing in 1991 a Stirling engine that runs with a temperature differential of only 1°F.

A year later, I made a model for NASA optimized to run on the warmth of human hands. NASA used this model (dubbed the N-92) to demonstrate Stirling engine principles as they contemplated the use of advanced Stirlings for powering space stations and planetary vehicles from solar or nuclear energy.

An Introduction to Low Temperature Differential Stirling Engines provides complete plans and tips for making the NASA N-92 engine. It also tells and illustrates the complete story of the development of these fascinating engines, which began in 1983 with the late Prof. Ivo Kolin of the University of Zagreb.

—James Senft, Ph.D., Emeritus Prof. of Mathematics University of Wisconsin-RF, River Falls, Wisc.

Very neat concept. Keep going! First comment: the print is too small. I'm an old man, but it's too small for anybody. Looks like the fine print of a legal doc.

I am looking at two projects in MAKE, Volume 01. First: the kite camera. But I think I'll get a radio controller from a model airplane or model car to rotate the camera to the right position and click the shutter, rather than mess around with Silly Putty for an unreliable timer.

Second: the card reader. I have an electronic workshop where I build electronic gadgets, not fix TVs. I already have most of the material called for, however I'll substitute a 74LS541 for the 74541 chip you call for. It's the same circuit and will run on 5 volts. A 7405 voltage regulator wastes a lot of current at 9 volts; how about four AAA batteries in series at 6 volts to the regulator, or a 4-cell rechargeable telephone battery? Don't cost much and it's available at RadioShack.

—C.P. Furney, Jr., age 81, Oak Ridge, Tenn.

MAKE AMENDS

In Volume 18, page 22, "Trailer (Re)Made," the trailer was bought through the General Services Administration (GSA), not the Government Accountability Office (GAO). In fact, GAO investigated problems with FEMA trailers.

In Volume 18, page 159, the Toolbox article "World's First Embedded Power Controller" should have been titled "Playing with Configurable Analog/Digital Chips" and displayed a picture of the FirstTouch Kit rather than the Cypress Power PSoC.

In Volume 17, page 137, "Elastic String Bass," the online schematics at makezine.com/17/diymusic_elasticbass have been corrected to show 440Ω resistors, not 440K resistors.

CLARIFICATION: In Volume 17, page 136, "1+2+3: Mechanical Image Duplicator," some readers mistook the second paper clip box for a second fixed anchor. It's simply a spacer to keep the duplicator level. With just a single anchor at the far left (as shown in Figure 3), the duplicator works great.

BY DAN WOODS

Make: Money

Really. I'm serious. We're going to make real money.

I admit it. I've always had this fascination with the world of counterfeiting. Selecting the paper, cutting the die, mixing the inks. I mean, if we ever do a spinoff called *Fake*, I want in.

Just imagine it. Every cash-strapped maker group, robot team, and science club in America will want to get their hands on a copy of *Fake: The DIY Currency Handbook*. "No maker left behind" will be our policy. Real, honest-to-goodness hands-on chemistry labs and metal shops returning to schools across the country. TechShops popping up in every town. Maker co-ops setting up shop and teaching classes in previously vacant car dealerships. And when Faker Faire comes to town, there will be Brink's trucks lined up for miles. It's the stuff dreams are made of.

Of course I'm kidding. (Honest, I don't know a thing about making fake money, so if you work for the Secret Service, chill.) But we did dream up a very cool way for schools, robot clubs, and ambitious maker groups to actually make their own money. Appropriately enough, it's called **Make: Money**. And it's not only legit, it's legal! So safe, in fact, even the Girl Scouts can get in on the action. Read on.

Make: Money works like this: when your organization sells MAKE magazine subscriptions to its members, the local community, friends, even strangers on the subway, it keeps 50% of every sale. Do the math: if your group sells 200 subscriptions, you just raised $3,400. No minimums and no maximums. We keep it simple. You sell your favorite DIY magazine, and we pay your group. Plus the top salesperson in your group gets a $50 gift certificate to the Maker Shed!

Since we can hear the gears turning, we figure a lot of you former scouts can't help but compare this to selling cookies. In fact, one of our editors reports that his daughter's troop keeps just a tad over 10% of every sale. At that rate, he says they'd have to sell 43.7 boxes of cookies to equal one subscription to MAKE magazine.

And how about that shelf life? The average life

Photograph by Sam Murphy

expectancy of those Thin Mints is maybe half an episode of *Make*: television, whereas we've yet to see an issue of MAKE magazine anywhere near a landfill. And don't even get us started on the educational value of reading MAKE compared to eating a box of cookies.

It's simple. Your school's science program needs money. Your FIRST robotics team needs money. Your maker club needs money. And we need more people learning about MAKE magazine. You help us and you help your group. Sell just one, or sell a million.

To register your organization, just send us an email at makemoney@makezine.com.

Dan Woods is MAKE's associate publisher and Maker Shed general manager.

Positive Externalities

Even though disabled people are numerous, they aren't so numerous as the able-bodied, and on average, they have less money than the rest of us. This is a vicious cycle.

Disabled people have less money, so manufacturers are less likely to make products for them, so the products they get cost more and are of lower quality. This leaves them with less money, which leaves manufacturers less apt to address their needs. And so on.

But sometimes a technology made primarily for the able-bodied has a side effect that helps the disabled. That's called a *positive market externality*. For instance, a disabled person doesn't need to wait for a special-needs manufacturer to turn out a great audio player for listening to text-to-speech and audiobooks. She can just buy the same cheap, commodity players that we all buy.

Unless the greed of a small band of vocal dinosaurs gets in the way.

And that's *just* what happened earlier this year, when Amazon shipped the latest version of its ebook reader, the Kindle, and included a feature that allows any text on the device to be converted to audio through some text-to-speech software. This aroused the ire of the Authors Guild, a moneyed, litigious pressure group that represents a paltry 8,500 American authors.

The Authors Guild claimed that the Kindle violates copyright (a ridiculous idea to anyone who understands copyright: even if converting an ebook to an audiobook infringes copyright, it's not illegal to make a device that can infringe copyright, otherwise we'd have to get rid of every camera, phone, computer, photocopier, and iPod in the world), and demanded that Amazon pull the feature.

Amazon caved, saying that they'd allow authors to opt out of having the text-to-speech feature enabled, and around the country, disabled rights groups let loose a shout of dismay.

The Authors Guild argued that the Kindle is impossible to operate if you're totally blind. Even if they're right (they aren't — many blind people routinely memorize sequences of physical motions that are performed on largely featureless surfaces, and many more have friends who can cue up an audiobook on their Kindles for them), the universe of disabled people who stand to benefit from the Kindle is much larger than just those who are totally blind.

All you need to do, blind people (says the Authors Guild), is abandon the value you get out of externalities from the market for the able-bodied, and limit yourself to the overpriced, underperforming devices developed as an afterthought in the market.

The Authors Guild will get their comeuppance, of course. So will we all. For though I write of disabled people as "them" and able-bodied people as "us," it's a near-certainty that I will end up with one or more profound disabilities if I live out my natural lifespan. It's a rare person who goes into his seniority with all of his senses and faculties in perfect running order.

Because when it comes to assistive technology and externalities, there is no "us" and "them." We're all in the same boat, reliant on technology developed for toy robots to build our ingenious maker projects, reliant on text-to-speech for the day when our eyes dim or our hands stop obeying us.

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

Photography by Michelle Stitzlein

Magical Moths

Whether she's building 11-foot-wide moth sculptures or creating crafts out of bottle caps with children, **Michelle Stitzlein** is attracted to bold, colorful designs and strives to be resourceful in her work.

Stitzlein's series of 14 moths combines her bold sensibilities with a grounding in recycled goods. She estimates that 85% of the materials in her moths — ranging in size from 3 to 11 feet — are recycled.

The sculptor, 41, scavenges for materials at yard sales, in her father-in-law's barn, and at a nearby, defunct dump. She also gets anonymous back-door deposits by neighbors. "Friends and family clean out their garage and basement and think of me just as they are about to throw things into the trash can," Stitzlein proudly admits.

A graduate of the Columbus College of Art and Design, Stitzlein lives with her artist-husband Nathaniel in Baltimore, Ohio, in a 1952 two-story, concrete block Grange building they've converted into a combination house and shared studio space.

She's traveled to developing countries like Guatemala, Mexico, South Africa, Peru, Colombia, and Namibia, and enjoys seeking out and meeting local folk artists. She's inspired by artists like Helen Martins of South Africa and Nek Chand of India, who've created entire sculptures out of recycled materials.

Not content to just make things, Stitzlein also tries to promote creativity by leading lectures, classes, and workshops. After an invitation from an elementary school to work on an Earth Day art project, she expanded and developed her ideas for child-friendly garden installations and "cap-by-number" murals. She wrote and self-published *Bottlecap Little Bottlecap*, a book about recycled art projects for kids utilizing colorful, easy-to-gather plastic bottle caps.

Stitzlein finds it exciting and challenging to develop her craft in new directions. After completing her moth series, she's forging ahead with a new sculpture series that's more abstract but still derived from nature. "It is truly tough work! Mind, body, and soul are tested and pushed to explore previously off-limits territories." —*Bruce Stewart*

More Sculptures: artgrange.com/michellesculpture.html

Cardboard Shredder

Hollow-core surfboards have always been a little off the wall, but none has looked as radical as **Mike Sheldrake**'s wave vehicles. A Sheldrake board is stunningly transparent. Its core is a matrix of ribs running three directions. There's no foam, just fiberglass skin over computer-cut cardboard.

Sheldrake, 34, has surfed since he was 9, but he'd never made a board — or made anything, really — until he got fed up with web programming three years ago. He craved something tangible to show for his work. He dreamed of creating a wood surfboard, and told himself, "I'm going to use my programming skills, but this time I'm going to make something."

He'd aced calculus, so he could handle the curve math. But for the structure? "I thought I'd go a different way from the 90-degree designs most people do," he says. "Triangles are stronger." He sat in a café sketching, and hit upon a pattern of triangles and hexagons he calls the *quarter isogrid*.

After a week of designing, he was convinced it was doable. Six months later, his cardboard prototypes actually turned out tough enough to surf.

In his garage in Orange, Calif., Sheldrake cuts the ribs from ordinary 4mm corrugated cardboard, using a Next Wave Automation CNC Shark fitted with a RotoZip spiral saw. Each cross-section is output from his own surfboard CAD software, rendered by his network of Linux, Windows, and Mac machines. When the last piece is cut, he slots it all together, and then skins it in fiberglass and epoxy resin.

Prototype problems are what you'd expect — leaks and delamination — but Sheldrake says his boards are standing up to typical abuse in the surf zone. Soon he hopes to help surfers design their own boards on his website and then buy pre-cut kits to assemble. But first he's investigating better rib materials, Gore-Tex vents, and other improvements.

Why go cardboard? It makes lighter longboards, he says, and leaks can be dried in a day instead of weakening the board over time. Best of all, instead of buying $900 boards, he can now make them for about 150 bucks. *—Keith Hammond*

Cardboard Surfboards: sheldrake.net/cardboards

Photography by Noah Webb

Photograph by Clayton Bailey

Mad Bots

In 1976, **Clayton Bailey** made a robot costume when he worked as a barker for his tongue-in-cheek Wonders of the World Museum in Port Costa, Calif. By way of necessity or chance, he says, "I became a robot myself ... and it just snowballed from there."

Since then, Bailey has made about 100 life-sized robot sculptures, all carefully constructed from found objects whose previous incarnations contribute something unique. For over 30 years, he's been collecting battery-powered toys, discarded home appliances, sports equipment, and bicycle and car parts from flea markets and scrap metal yards.

"I started making them with ceramics, but it was too heavy and difficult to make large robots, so I switched to aluminum that can be cut with tinsnips and hacksaws," he says. "I get a kick out of figuring out how to put them together with rivets, nuts, and bolts. [This] is a kind of figurative sculpture. You create a character."

These characters aren't just visual — some are semi-functional. While they aren't likely to clean your house or engage in meaningful dialogue, they are endowed with components such as blinking eyes, flapping metal wings, "high-voltage mercury vapor-powered digestive tracts" and "shiny breasts tipped with blinking rubber nipples."

Sparky Robot relates through electronic meters and is powered by an ordinary 110-volt AC wall plug. *Starbot* provides news and entertainment via AM/FM radio and a stereo tape deck. *Giant Metal Robug*'s appendages move in the wind to discourage garden pests. *Marilyn Monrobot* "has traveled around the world as a goodwill ambassador and a beauty queen for the robot revolution," not to mention being corrosion-resistant, fireproof, and unbreakable.

Bailey lists *Mad* magazine and the Johnson Smith Company as two notable influences, and it's easy to see a similar playfulness in his own work. On his website you'll find more of his creations plus his Studio Cam, which tracks his daily progress from inside the workshop. *—Thomas Walker Wilson*

He Gots Mad Robots: claytonbailey.com
Clayton Bailey Profile: makezine.com/go/bailey

Faux Favela

The first thing you're likely to notice about **Benjamin Van Oost**'s *Favela* is that it's made entirely of trash — recycled boxes, pieces of metal found on the street, toilet paper rolls, aluminum cans. And at a little over 1 meter in height, the sculpture appears as burgeoning and claustrophobic as the real thing.

Favela is a Portuguese word most commonly translated in Brazil as "shantytown." Built from materials ranging from bricks to garbage, favelas are plagued by sewage, crime, and hygiene problems. In most cases electricity is illegally tapped from the public grid. As a general rule, Brazilian cities do not recognize favelas as legal entities.

Dutch artist Van Oost began to conceive of *Favela* in 2007, with his girlfriend Annelies, after seeing the Brazilian film *Cidade de Deus* (City of God).

"The movie certainly inspired us in a way, but to be honest, we started building the *Favela* just because we felt the need to create something out of nothing," Van Oost says. "We didn't make any sketches before we started building and we didn't know what the result would be."

And it was only after seeing the work of Congolese artist Bodys Isek Kingelez — "his maquettes, his utopian, modernistic architecture" — that the actual building process began. "The *Favela* originated in a creative 'rush' where we didn't really know where it was going," Van Oost remembers.

Van Oost, along with collaborator Mathieu Van Damme, founded Toykyo Productions, a design agency and production company, in 2007. Their projects include a cardboard backdrop used in a campaign for sleeping pills, decor for fashion shoots, and life-sized statues in polyester. They also design T-shirts and do limited screen prints and graffiti.

Favela hasn't yet been publicly displayed, but it has a place of prominence in Van Oost's home in Belgium and is featured on his company website. "Everyone can have their own interpretation of the work, can create their own story within this microworld," he enthuses. —*Thomas Walker Wilson*

More Toykyo Work: toykyo.be

Photograph by Benjamin Van Oost

Photograph by Floyd Fronius

Open Source Soaring

We may all dream of flying silently through the clouds, but **Mike Sandlin** has actually created a set of gliders that allow you to fly with only the power of gravity.

Using his expertise in building hang gliders, Sandlin prototyped a slow-flying, ultralight sailplane that he calls an "airchair." Airchairs are basically hang gliders with seats, that steer like an airplane. Beginning with his Basic Ultralight Glider (Bug) in the 1990s, Sandlin has pioneered a unique field of powerless aviation.

His airchairs include the biplane Bug series, monoplane Goat series, and his current creation, the rudder-steered Pig series. Instead of selling plans like most small aircraft designers, Sandlin provides the source CAD drawings free for download.

The airchair is designed to be loaded on top of a car for quick setup and disassembly. The pilot launches the glider by rolling down a small incline, usually at hang-glider launch sites.

Sandlin says his gliders are "intended to provide open air soaring, forgiving flight characteristics, convenient transport, simple 'garage technology' construction, and a high level of crash safety," all major accomplishments for machines that weigh less than 155 pounds.

The Pig (Primary Instruction Glider) is a biplane design that features a two-axis control system, which is much easier for beginner pilots. It's slow, but easy to fly, while still maintaining a decent level of safety for the pilot. Assembly can be accomplished in less than an hour with minimal tools.

Although Sandlin prefers to avoid working with motors, his design has incorporated a space for a small pusher motor attachment on the Pig. With a small motor, the Pig could hop between thermals, staying airborne for hours on end.

So, when will Pigs fly? As it happens, they're flying right now, and with Sandlin's help, you could fly a Pig of your own!

—Abe Connally and Josie Moores

» **Basic Ultralight Gliders:** makezine.com/go/glider

Photograph by Cesar Ortega

Bus Tag

Magda Sayeg likes to see knitting on everything. In fact, since 2005, the Austin-based artist and her group of urban knitters, Knitta Please, have gone on several covert midnight missions to knit cozies for car antennas, street sign poles, trees, scooter handlebars, and even a brick on the Great Wall of China.

So when the 35-year-old mother of three saw a broken-down bus that was being used as a ceramics studio in Mexico City, she just couldn't resist. She had to cover it in knitting.

But something this large was going to take more than a few stealthy hours in the middle of the night, so before "tagging" the bus with yarn, Sayeg obtained permission with the help of a local art gallery, Elaboratorio.

Then, with a crew of six very dedicated knitters, it took four days and a "gazillion" skeins of yarn (she admits it was probably closer to 500) to complete the project.

The bus, which sits alongside a city park, has constant foot traffic, and Sayeg received heartfelt reactions from all kinds of strangers during the process. "I love when an old fellow comes up to the bus and smiles in a kind of way that makes you think he may not smile often," she recalls. "He reached out and touched the bus and then went on his merry way."

When Sayeg isn't stitching up city fixtures, she's busy with her line of whimsical felted scarves, which she sells at her Houston clothing shop, Raye (rayehouston.com).

But if she could figure out a way, she'd like to focus on Knitta full time, maybe doing a few more large-scale projects. "It's still really wonderful and satisfying to wrap a stop sign pole in knitted material, but, I must say, it is breathtaking to wrap a city bus in it."

—Carla Sinclair

More Knitted Art: knittaplease.com

All We Can Say Is, WoW

MIT Media Lab research assistant **Cati Vaucelle** knows the pressures of being a hardcore gamer. The max-level *World of Warcraft* (WoW) player was co-general manager of her guild before taking a break last September to focus on Ph.D. exams. But she never stopped thinking of the game.

With help from artist **Marisa Jahn** and **Steve Shada**, Vaucelle created the WoW Pod, "a cocoon that structures a relationship between your physical body and your avatar," she says, and provides for advanced players' every need.

The closet-sized, hexagonal hut features a cone-shaped roof, Viking horns, and wood walls mimicking the videogame's Orc architecture. Inside it's homier, with a computer screen and keyboard, digital surround sound, and a wood-stained throne with built-in toilet — eliminating bothersome bathroom breaks.

The Pod's centerpiece is its AFK ("Away From Keyboard") Cookset, a kitchenette equipped with fresh spring water, cook pot, and automated stovetop, inspired by Vaucelle's overheating MacBook.

Utilizing a servo-controlled hot plate, a Semacode reader, and Vaucelle's self-written software, the AFK creates a dialog between a player's physical and digital worlds. Users pick from the Pod's eight hand-packaged mini-meals (a combo of fast snacks and instant soup) with game-inspired names like Roast Raptor and Lynx Steak. Once a meal is chosen, users scan a Semacode tag that activates the hot plate, adjusts cooking time and temperature, and triggers avatar behaviors such as culinary instructions, mealtime announcements, and napping while you dine.

Vaucelle says WoW players "love" the pod and cookset, but isolating gamers isn't her only intent.

"I [want] to look into the cookset as means to provoke exchange, discussions about the food lives of players in relation to their habits," she writes on her website. "They take care of their avatar — feed them, give them water, make them do crazy adventures. Now their avatar will take care of them."

WoW Pod is on display at the MIT Museum through September 2009. —*Laura Kiniry*

» **Sedentary Masterpiece:** makezine.com/go/wowpod

Photograph and Illustration by Cati Vaucelle, Steve Shada, and Marisa Jahn

COUNTRY SCIENTIST | BY FORREST M. MIMS III

How to Study Tree Rings

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

Tree Rings

In temperate and arctic regions, most trees are dormant during winter. When spring arrives, a sudden burst of growth expands trunks and branches with new wood formed from large cells and known as early wood (or spring wood).

As the growing season peaks, the growth slows, and the late wood (or summer wood) that's formed has cells with thicker walls. This late wood may appear much darker than the early wood when it contains more tannin.

Each year, this process forms a new growth ring, just beneath the bark of the trunk and branches of a tree.

Not all trees produce annual growth rings. Trees in the tropics that grow year round may have very suppressed annual rings or none at all. I learned this firsthand while sampling trees in Brazil during a field trip sponsored by NASA to measure the impact of severe biomass smoke on the atmosphere and plants.

Where I live in Texas, most trees are dormant during winter. But only some of these trees produce sharply defined rings. These include the red oak, hackberry, and all pine and baldcypress trees. The live oak keeps its leaves during the winter, and its rings can be difficult to count.

The Science of Tree Rings

Astronomer A. E. Douglass established tree ring science when he postulated that tree growth was influenced by climate changes caused by the solar cycle. He developed and taught classes at the University of Arizona on *dendrochronology*, the science of dating trees by studying their rings. In 1937 he established the university's Laboratory of Tree-Ring Research.

Douglass showed that archaeologists could use growth rings to date the timbers used to build ancient structures. Annual growth rings in trees also provide valuable information about past precipitation, climate, major volcano eruptions, and forest fires. They permit long-ago floods and landslides to be dated.

How to Obtain and Prepare Tree Ring "Cookies"

You can learn to do tree ring studies by using slices, or "cookies," cut from trunks and branches. Christmas trees are an excellent source, as are building and road construction sites. Professional tree trimmers and landscape crews may be willing to provide you with samples. Firewood may also provide good sample material. Another way to find samples is to keep an eye out for piles of recently cut and discarded branches.

You can even use cross-sections sawn from lumber, although these will not form round cookies. If you use this method, try to find dated lumber that includes the outer edge of the original trunk so you can determine the age of the rings.

If you have trees or access to trees where you live, you can cut branches or collect cores from trunks. If you're not the landowner, be sure to get permission first. This is especially important if you want to obtain samples from trees on private land or land owned or managed by cities, states, or the federal government.

When possible, use a sharp, fine-toothed wood saw to slice cookies from branches and trunks. Living wood should be allowed to dry for a day or two before smoothing it with sandpaper. I usually begin with 100-grit sandpaper followed by 220 grit. The final polish is made with 400 or 600 grit.

Samples cut with a chainsaw can be used, but they'll require much more surface preparation. If possible, smaller samples cut with a chainsaw should be recut with a handsaw. You can use a power sander to smooth the rough faces of these samples.

For small samples, I prefer to use a handheld plane such as the Stanley 21-399 6-Inch Surform Pocket

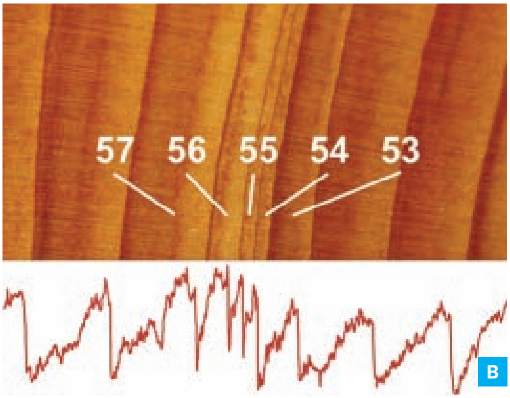


Fig. A: Cross-sections from two varieties of baldcypress felled by a Texas flood. Fig. B: Narrow rings in this baldcypress accompanied a 1950s drought; ring chart by ImageJ software. Fig. C: Century-old Norway spruce felled by chainsaw. Fig. D: You may need permission to take tree "cookies" across international borders, so take photos.

Photography by Forrest M. Mims III

Plane. This tool will quickly remove burrs and other saw marks.

Large trunk cross-sections require considerable time to prepare. A local cabinet shop once smoothed some large baldcypress sections that I had used a chainsaw to remove from trees knocked down by a major flood. But the cabinet shop couldn't handle the largest section, which was more than 3 feet across.

How to Examine and Photograph Tree Ring Samples

Your sample is ready when it's been sanded smooth to the touch and has few remaining saw marks. If the polished side of the sample looks good, flip it over and use a ballpoint pen or fine-point Sharpie marker to write the species and the date and place where it was collected.

It's best to examine the rings with a magnifying lens or a 10x loupe. Note that individual rings may be dark on the side nearest the bark and light on the side nearest the center. Be careful to count these two differences in shading as one ring and not two.

The first thing I do is count the rings by their year, beginning from the first one inside the bark. You may want to place a mark at each tenth year. Ideally, try to determine the date when the branch or trunk began growing. After you determine this date, print it on the backside of the sample.

Professional tree ring analysts use various stains to highlight rings that are faint and difficult to see. You can even use water. Just moisten a paper towel in water and lightly stroke it across the sample.

You can make photographs or digital scans of your tree ring samples for more detailed analysis and for display online. I've used scanners and digital cameras with a close-up setting. Try moistening samples as described above to enhance visibility.

Because of international travel restrictions, if you collect samples outside your country it's best to leave them behind and bring home only their photos.

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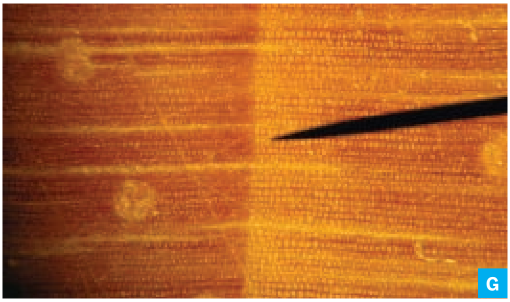

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Fig. E: This sequence of "cookies" cut from a branch at the top of a fallen pine tree allows its growth to be carefully analyzed. Fig. F: This Norway spruce log was used to build a cabin in Switzerland. Experienced dendrochronologists can compare these rings with those of logs with known dates to determine when this log was cut. Fig. G: This microscope view shows the boundary between two growth rings in a pine branch cut by landscapers at Mauna Kea State Park in Hawaii. Growth is from left to right.

You can use various photo processing programs to further enhance the visibility of the rings. And you can use ImageJ and other image analysis tools to help count the rings and study their color differences. ImageJ requires no license, and the program is freely available at rsbweb.nih.gov/ij/index.html. (*See "Country Scientist" in MAKE, Volume 18, for more about ImageJ.*)

Going Further

There are some excellent websites devoted to tree rings. By far the most comprehensive is Dr. Henri D. Grissino-Mayer's Ultimate Tree-Ring Web Pages at web.utk.edu/~grissino. This site includes a superb collection of tree ring images, background information, tips, and links to other tree ring sites.

Tools known as increment borers are used to extract cores of wood from living trees without having to cut down the tree. Suppliers of these tools are listed on the Ultimate Tree-Ring Web Pages. In my experience, an increment borer can never replace a full cross-section, but they're invaluable when cross-sections of trunks are simply unavailable. These tools are much easier to use in conifers than in hardwood trees, as I found out while working up a sweat coring hardwoods in Brazil's Amazon basin.

Forrest M. Mims III (forrestmims.org), an amateur scientist and Rolex Award winner, was named by *Discover* magazine as one of the "50 Best Brains in Science."

1+2+3 Custom Memory Game

By Julie A. Finn

You can make it!

Memory is basically the perfect game. A kid can play it solo or in a group, it can be easy or challenging, and it's educational to boot. Give an old standby some new flavor and create a perfect rainy-day activity when you make your own memory game out of materials you already own.

YOU WILL NEED

- **Paper** plain, colored, or printed, for making matching image pairs
- **Scissors**
- **Glue stick**
- **Laminating sheets or a laminating machine**
- **Fancy paper** such as scrapbooking or wrapping paper, for the faceup and facedown sides of your memory cards

1. Prepare your pairs.

Cut out several sets of matching image pairs from paper, such as numbers, colors, or words. (Here I used paint swatches.) If necessary, trim them all to be approximately the same size or to cut off extraneous words or images.

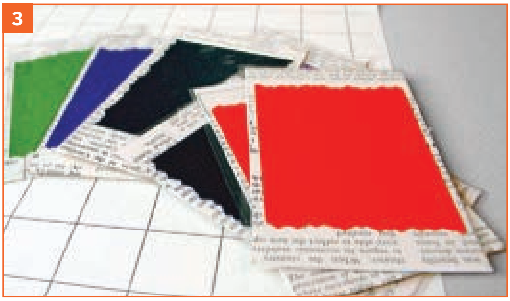

1


2

2. Prepare your template and backing.

Find a template for your memory cards — cassette tape, coffee mug, etc. — and cut out identical faceup sides from your fancy paper for each card in your game.

Also cut out a facedown side for each card — this can be from the same or different paper as your faceup side. These don't have to be identical, because they won't be facing up at the start of the game.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3. Glue and laminate.

With a glue stick, lightly stick your faceup and facedown sides together (facing up and down!), then stick one memory game image on each facedown side.

Laminate your cards for durability, or take them to a copy shop to be laminated.

Use It.

While simple identical color matches work well for a memory game, consider tweaking your game toward a specific educational experience or a specific kid. Try matching colors with color words, for instance, or pictures with Spanish words, or math equations. Keep your kid guessing!

Photography by Julie A. Finn

Julie A. Finn blogs about all the wacky hijinks involved in parenting and the crafty life at craftknife.blogspot.com.

HANDS-ON: Engineer Ugo Conti in his home workshop, where he designed the wave-absorbing *Proteus*, an ocean-crossing boat that sits high above two 100-foot-long inflatable pontoons.

A Feel for Engineering

Ugo Conti's *Proteus* boat reflects a unique instinct for design.

By Todd Lappin

Humans have been building ships for thousands of years, but it took a retired engineer working in his garage to figure out a way to span the seas without rocking the boat.

At his hillside home overlooking San Francisco Bay, Ugo Conti designed and built *Proteus*, a prototype of a radical new class of watercraft that looks like a cross between a common waterbug and an invading spaceship from *War of the Worlds*.

Called the Wave Adaptive Modular Vessel, or WAM-V, Conti's innovative design solves a problem that plagues all conventional boats: maintaining a smooth ride while traveling through big waves and pounding surf.

To accomplish that, *Proteus* is built on a pair of 100-foot-long inflatable pontoons with a cabin suspended by a set of arches 20 feet above the water. The pontoons are articulated and the arches are flexible, so *Proteus* adapts to the changing contours of the ocean's surface in much the same way that the independent suspension of a car absorbs big bumps to give passengers an easy ride.

As an added bonus, the WAM-V configuration is also extremely fuel efficient, enabling *Proteus* to travel 5,000 miles while carrying just 2,000 gallons of onboard fuel. All told, the idea works so well that it has attracted the interest of the U.S. Navy's Office of Naval Research, which is evaluating *Proteus* for possible military use.

Superficially, Conti is an unlikely candidate to revolutionize ocean travel. Born in Italy, he emigrated to the United States in 1965 and got a Ph.D. in geophysics and oceanography from the University of California at Berkeley. For much of his professional career he worked as an electronics design engineer, specializing in low-frequency antennas and geophysical instrumentation systems. Along the way he dabbled with boats in his spare time, including several that he built and sailed himself.

Photograph by Robyn Twomey


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Now 70 years old, Conti still spends his days building things in his garage workshop, and he remains a hands-on maker. I sat down with him to find out more about the development of the WAM-V and how he learned to solve very old problems in very new ways.

Todd Lappin: What made you decide to become an engineer?
Ugo Conti: I was born an engineer. That's what I am. The instinct of wanting to understand how things work and using that understanding to do something, to make something — in my case that started at a very early age. I have intuition about how things work. I understand certain simple things, like the laws of physics, for instance, without mathematics. I'm not a mathematician. I don't do mathematics.

TL: You're just a very hands-on person?
UC: Yes, absolutely. Learning is extremely difficult for me. It's not easy to study. I have a hard time remembering things. Then how did I get a Ph.D. at Berkeley? I'm a very normal person, but I have big peaks. It impresses people, because I can approach a problem without knowing anything about it and come up with a solution. It may be a problem people have been working on for months, but I solve it quickly, just out of intuition. It's a gift. I was born with it. People look at the peaks and think I'm a genius. Well, yes, in the peaks I am, but most of the time I'm just normal. In fact, I make a lot of mistakes. I mean, one mistake after the other.

TL: What was the inspiration for the unusual design of *Proteus*?
UC: I get seasick. I suffer from motion sickness. When I sailed around the world on a regular big sailing boat, that was a big problem. When an engineer has a problem, he wants to find the solution. He wants to make something to solve that problem. The problem was motion. At sea, motion is a problem. And it's not a problem only for motion sickness, but also for stability, for safety, for all sorts of things.

Also, I think if you go down deeper, I'm motivated to do something that doesn't exist. There's an attraction to that. I'm not copying something; I'm doing something completely new. That's how I ended up in the boat business, even though I'm not a professional boat builder or designer.

TL: What about the unusual configuration of the WAM-V? Where did that come from?
UC: Originally I was thinking about building a flexible sailboat, with a flexible mast. I always wondered why masts aren't flexible. That's how it works on a windsurfer. On a windsurfer, a person uses their body to adjust the position of the mast. The person provides active control and flexibility, because if the wind picks up, you don't stand stiff and rigid. You adapt automatically because the mast is always pivoting.

Insects and bugs work in a similar way. They not only have great control, but they also go through obstacles very quickly because they're flexible.

TL: That sounds more like biology than naval architecture.
UC: In fact I studied ants and so on. I was studying insects and how they have many legs. All those legs are controlled and flexible, so it's OK because you can always keep them where you want.

TL: Those ideas led to the development of your early models?
UC: Yes, I made a model of the boat that eventually became *Proteus*, and put it on the living room floor. That's when things started to happen.

I've learned that big projects have three stages: fantasy, dream, and plan. The fantasy stage is all in your head, obviously, but eventually you decide you're ready to get a little bit more real. The dream stage is where you actually start thinking about the project in practical terms. After the dream you start planning. You go into planning and doing, and that's when reality strikes. You never succeed in fulfilling a fantasy, almost by definition, because it's just a fantasy. But the fantasy is what catches the imagination and provides motivation.

TL: What was the hardest setback you encountered while building *Proteus*?
UC: I started this project by building a prototype — a 50-foot prototype I built in the garage.

“The good thing is that if you’re ignorant, you don’t know what cannot be done.”

Photography by Marine Advanced Research, Inc.

EASY RIDER: *Proteus* is a WAM-V boat, a Wave Adaptive Modular Vessel designed with flexible hulls that conform to water surface movement, absorbing the energy in much the same way that an automobile’s suspension cushions the rider (or unmanned payload) from bumps in the road.

I designed it out of carbon fiber, and we spent a lot of time on it. But on the day we launched the prototype, the carbon fiber broke almost as soon as the boat hit the water. Why? It broke because I didn't know how to design with carbon fiber. Mistakes. I mean, I make a lot of mistakes. That's when I decided to forget about carbon fiber and use titanium instead.

TL: That sounds like a nightmare!
UC: Yes, but I once gave a talk entitled "The Role of Ignorance in the Creation of a New Species." I'm basically an ignorant person who knows very little, because I don't have a good memory. The good thing, though, is that if you're ignorant, you don't know what cannot be done. All my life — professional life, university life, and so on — I always took advantage of that, by not knowing what couldn't be done. That's how I've been able to think outside of the box. Because I am ignorant, I just start by making or designing things.

TL: What does being an engineer mean to you?
UC: Engineers look for solutions. That's what engineering is for me. Engineers see something and have a physical thing as a goal. But I am an old-fashioned experimentalist. I put my fingers into electronic circuits to see if they work. I did that for decades, successfully. If something doesn't work, I kept sticking fingers in until I find out what's wrong.

TL: So, your approach to making things is very empirical? It's about just doing it and seeing what happens, learning, making mistakes, then fixing them?
UC: Yes, it's essential for me to make things physically, but I design in my head. I can think of what to do physically by visualizing something mentally. I see things in 3D, and I can turn them around to feel if they work or not. It's as if someone were explaining to me, "OK, now I'm going to weld this to that, and this will do that, and oh, that tube is a little bit too small," and so on. On most days I wake up at 5 o'clock in the morning, and I stay in bed for an hour or more doing that.

TL: Why is the U.S. Navy interested in *Proteus*?
UC: The Navy is very conservative, but they are interested in adapting the WAM-V for use as an unmanned vehicle. It has a lot of advantages. First of all, it collapses, so you can put it into a box, open it up, throw it in the water, and it's ready to go. It's also very difficult to overturn, so it can stand up to bad weather. It's extremely stable, so it's a better platform for sensor systems. And it's scalable.

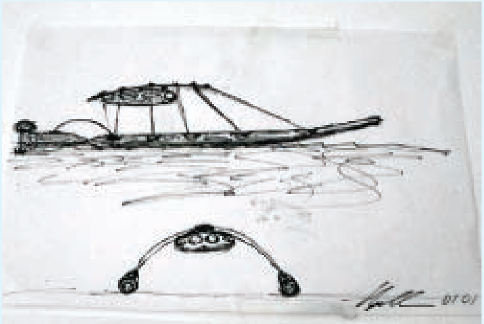
We have a contract to build a 12-foot, unmanned version of the WAM-V. We're collaborating with Florida Atlantic University. They're going to do the unmanned systems — the brain — and we're building the boat — the body — using improvements that we learned from *Proteus*. We'll see if the Navy decides to pick it up or not. It may take five years, but that's fine, because I'm also interested in other things.

TL: What are some of the things you still want to do, apart from working on the WAM-V?
UC: My wife is terrorized. She says, "When you finish this, what do you do? You'll be bothering me all the time." I say no, I'll find something else. I always do.

Well, the next thing that seems to be coming up in my mind is to return to a musical instrument I designed and built during the 1980s. I've always liked whistling because it doesn't require any formal learning. I don't know music, but I've

Proteus Wave Adaptive Modular Vessel (WAM-V)

Length: 100 feet
Beam: 50 feet
Displacement: 12 tons, fully loaded
Payload: 4,000 pounds
Draft: 8 inches forward, 16 inches aft at half load
Fuel: 2,000 gallons
Range: Roughly 5,000 miles
Speed: 30 knots, maximum
Passengers and crew: Berthing for up to 4 people
Materials: Titanium, aluminum, and reinforced fabrics
Cabin: Control bridge and modular sleeping quarters
Pontoons: Inflatable, six-chamber hulls with articulated engine pods
Engines: Two Cummins MerCruiser Diesels, Quantum Series QSB5.9, 355 horsepower each
Transmission: TwinDisc MG-5061 A marine gears with Arneson ASD 8 surface drives
Suspension: Titanium springs



SENILITY AT WORK: Conti spends most of his days in his garage workshop building small models and prototypes of his boats (clockwise from top left): Early conceptual prototypes for the *Proteus* WAM-V; a flexible pontoon built for Conti's 12-foot *Proteus* prototype; Conti's preliminary sketches for the *Proteus* reveal the basic shape used in the actual vessel; Conti's small model of *Proteus* used flexible, shock-absorbing wires to connect the pontoons to the cabin.

Photography by Todd Lappin and Robyn Twomey (top right)

whistled all my life. At a certain point, I designed a whistle synthesizer. It takes the whistle and comes out a different sound — same note, same everything, but different. But that was 30 years ago, so it was all analog and heavy. I plugged it in recently to see if it still works, but it's not working very well. It's a rat's nest of wiring inside, but I don't have the foggiest idea how to fix it because I never made any circuit diagrams.

Now the technology has advanced to a point where it can be made much smaller and faster. I want to develop a modern version of it. It's basically a software problem, which is something I can't do, but I can pay somebody to do it, because I know what I want. I want the sounds that come out to be very sophisticated.

TL: That sounds like a great project!

UC: Well, when people ask me why I decided to get into building things like the WAM-V, I blame it on senility. To go really crazy like this, you need to be senile in the sense that when you get older, one of the very few advantages is that you don't have any more responsibilities. And without much responsibility, you can go off. You can go out of the box. You don't have to be prudent. That kind of freedom is what allowed me to go crazy with this thing.

For a video of Ugo Conti's WAM-V in action visit makezine.com/19/ugoconti.

Todd Lappin is an amateur military vehicle scholar, a product strategist, and a consultant.

Homestar

Takayuki Ohira creates planetariums for everyone. By Lisa Katayama

Takayuki Ohira made his first planetarium when he was 10 years old. It was a simple desktop device with tiny holes burned into sheets of paper and illuminated with light bulbs. Now 38, Ohira is the inventor of the Megastar — the world's most advanced planetarium projector, according to the Guinness Book of Records. And he does it all by hand in his tiny office near Tokyo.

After building several pinhole versions as a teen, Ohira became obsessed with the idea of creating a much more complex planetarium. He experimented with techniques acquired through his part-time job at a power supply devices company, often working past midnight in his parents' foyer.

His neighbor, an engineer at Canon, helped him design software to interpret the star data he bought on two floppy disks from the United States. He mapped the latitudes and longitudes on paper, divided the sky into 32 segments, transferred those images onto sheet metal, and then illuminated it using multiple projection lenses.

"If someone told me I couldn't do something, it just made me want to try harder," Ohira says. He completed his first optical lens projection planetarium, called the Astroliner, when he was 21. No amateur had ever succeeded in making one; it was something that only companies with a full staff and several years' worth of funding usually attempted.

Ohira graduated college and got a day job as an engineer at Sony, but he was back in his bedroom laboratory by night. Determined to make an even more intricate planetarium before anyone else did, he bought his own laser, on credit.

In 1998, at the age of 28, he unveiled the Megastar, a 3-foot-tall portable planetarium encased in a blue steel cover. He bought a plane ticket with the

“I believe in the beauty of details, even those you can’t see with the human eye.”

STARSTRUCK: Takayuki Ohira’s portable planetariums enable consumers to project the night sky anywhere — with precision.

last of his savings (the project had cost him nearly $20,000) and took it to London for the annual International Planetarium Society conference.

Attendees were stunned — nobody had seen such precision in a planetarium before. The Megastar displayed more than 1 million stars — the human eye can only see about 10,000 in the sky, so most people don’t bother to make many more than that.

To Ohira, accuracy was important. “Most Westerners were more puzzled by why I did it than how,” he remembers. “They didn’t see the point of showing stars that weren’t entirely visible. Obsession with quality is very Japanese. I recognized that groupings of small invisible stars lightened the Milky Way. I believe in the beauty of details, even those you can’t see with the human eye.”

Once he returned to Tokyo, Ohira continued to develop the new projector, alone in his bedroom. After five years he quit his job at Sony, rented an office, and hired an associate to help do PR for his new planetarium company. He started downloading maps from the European Space Agency website — “theirs are the most consistent” — and started working on Megastar 2, which had more stars, less mass, and even greater attention to detail.

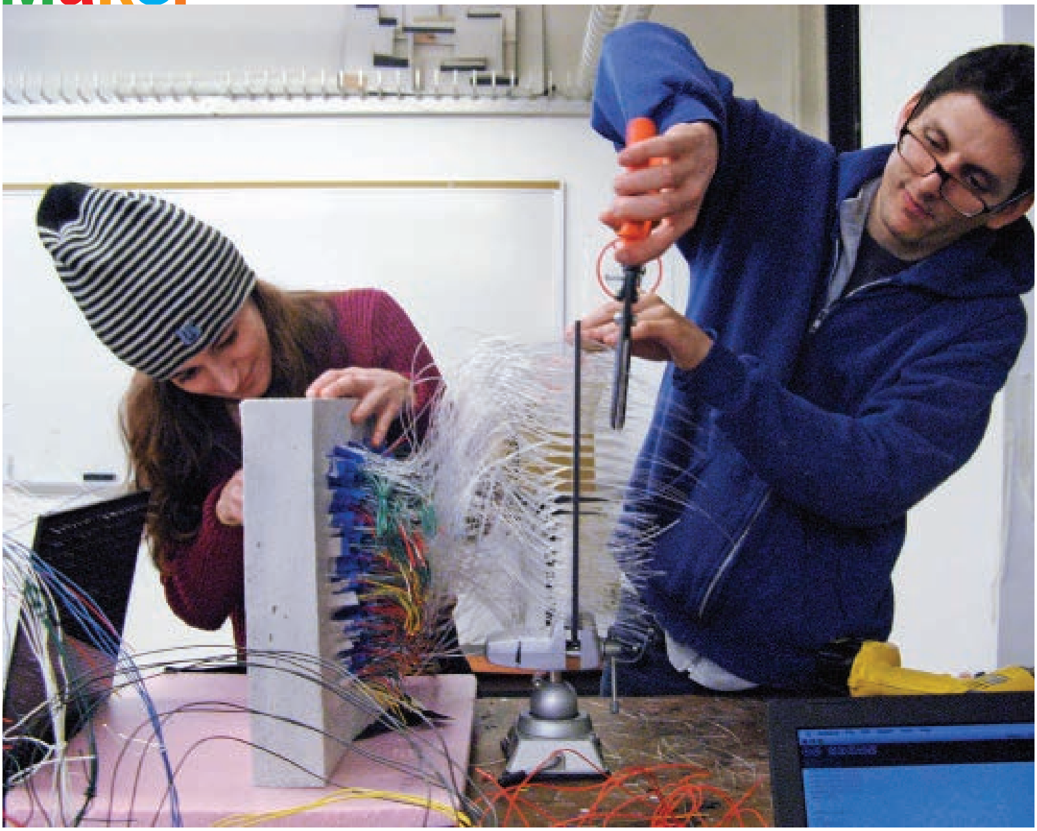
Sega Toys tapped him to make the first portable planetarium for home use; the Homestar, a desktop-sized $200 optical lens planetarium displaying 10,000 stars, hit consumer space in 2005. Spinoffs, such as planetarium cellphone straps and floating planetariums for baths, quickly followed.

Sega upgraded to the Homestar Pro in 2007 with 60,000 stars, followed in 2008 by the most advanced home planetarium, the Homestar Extra, 15 times brighter than the original and with 120,000 stars.

By now a household name among enthusiasts in Japan, Ohira is currently working with everyone from the national space agency to video game companies to apply Homestar and Megastar technologies to their ventures. He’s also working on Megastar 3, the ultimate, beyond-digital-plus-optical planetarium extravaganza that he promises will blow all his previous work out of the water.

“It’s going to be something that’s never been done before,” he says excitedly. Nobody would expect any less from him.

Lisa Katayama writes for *Wired*, *Popular Science*, *New York Times Magazine*, and her own blog, TokyoMango. She’s an editor at Boing Boing Gadgets and the author of *Urawaza*.



Set in Stone

An interactive concrete interface. By Ithai Benjamin and Vikram Tank

S*et in Stone* is two concrete tables that interact with each other when touched. The tables' embedded LEDs are unlit, until you touch one table — then the other lights up. Each time a table is touched, it changes the pattern on the other.

We made *Set in Stone* for NYU's Interactive Telecommunications Program's Winter Show. The materials include a bag of concrete, a few hundred feet of fiber-optic cable, 400 LEDs, an Arduino microcontroller, and some LED drivers.

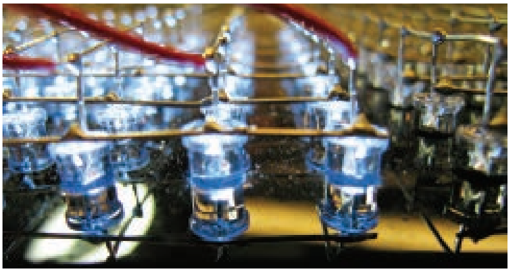
The concrete blocks are 13"×13"×2" and weigh 30lbs. They were cast with 400 fiber-optic cables and hookup wires. The LEDs were connected to nine LED drivers controlled by an Arduino.

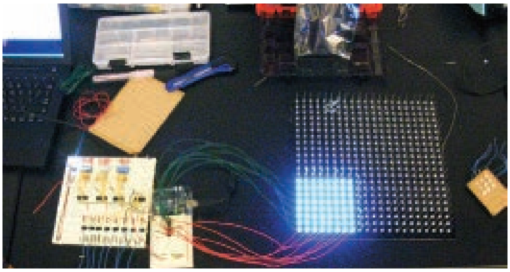
We laser-cut a grid of 400 holes into two 11"×11" plexiglass panels, which we used as an interface between the fiber-optic cables and the LEDs. One plexiglass panel had small holes to fit the fiber optics; the other had larger holes to fit the LEDs. To make the display touch-sensitive, we ran solid-core hookup wires from the concrete blocks to a QProx sensor, also wired to the Arduino.

Each LED shines through one fiber-optic cable. We inserted them into the holes of the appropriate plexiglass plate and wired them together. Wiring the LEDs is simple — the positive LED leads in each row are soldered together, and the ground leads are soldered together — but it's also tedious. After wiring, we connected the LED matrices to LED drivers, each of which controls an 8×8 LED matrix.

To cast the fiber-optic cables as a grid in the cement, we used a piece of 13"×13" foamcore board, poked holes in the foam (using our laser-cut plexiglass as a template), and stuffed it with the fiber-optic and wire pairs.

Photography by Vikram Tank and Ithai Benjamin





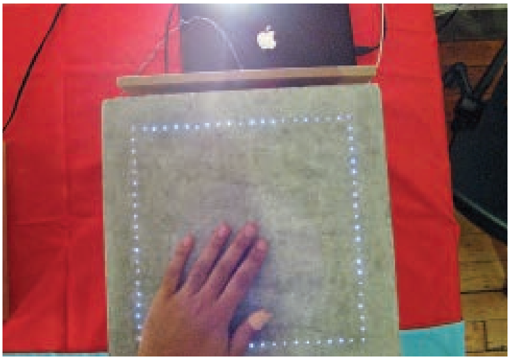


TABLE TALK: (counterclockwise from top left) LEDs' positive leads soldered in rows, fiber-optic cables aligned in foamcore, the two tables on display at the ITP Winter Show at NYU, testing the interface.

To pour the concrete, we built a wooden form using 1×8 lumber screwed into plywood. We used caulk to form a seal and sprayed the inside of the form with cooking spray so the concrete wouldn't stick. We used Buddy Rhodes Concrete Counter Mix because of its small aggregate (we didn't want large pieces of stone pushing the components off the grid).

We mixed the concrete to oatmeal consistency in a plastic bucket and spooned it into the mold. We were very careful to avoid disturbing the wires and the fibers. Once we had a good amount of concrete in the form, we whacked it with a rubber mallet from below for about 15 minutes to get the air bubbles out. We covered it in plastic and let it cure for 24 hours, then loosened the form and let the sides dry for another 24 hours before removing the form. Now we had a concrete block attached to a foam block.

The fun part is getting the foam off the concrete. It involves a lot of pulling and a bit of a mess. The basic idea is to get as much foam off in chunks as large as possible without breaking the wires.

After the foam was off, we plugged each of the fiber optic cables into the holes of the plexiglass. We used a flashlight to shine a light from the front of the concrete into one fiber at a time, allowing us to see where in the plexiglass grid it went. Fortunately, we had bunched the fibers into groups earlier, making the process go much faster. If we'd had to find individual fibers from a huge bundle we would have driven ourselves crazy. The fiber ends that poked through were trimmed flush to the surface of the plexiglass, so they'd be able to mate to the LED plate.

We made a stand for the block out of medium-density fiberboard, then we covered the MDF with kraft paper and shoved everything into the cabinet. After writing and debugging the code to control the LEDs, we were done.

Imagine one of these blocks on the beach in L.A. and the other on a sidewalk in Times Square. People could communicate between the two cities. It could also be installed in a kitchen, or anywhere at home. Pushing further, you could make these tables act as drawing tablets — tracing your finger on one would light up the other, following the drawing on the first one.

+ More images and info: setinstone.wordpress.com

Ithai Benjamin and Vikram Tank are completing their graduate studies at NYU's Interactive Telecommunications Program.

Capable: 204mph
Goal: Class record

SPEED RACER: Gary Calvert proudly stands beside his "blown gas lakester" on the playa of the Bonneville Salt Flats.

Speed Week

What Cape Canaveral is to astronauts, the Bonneville Salt Flats are to those who love to drive fast. By William Gurstelle

The Bonneville Speedway stands on part of the 30,000 acres of salt flats formed thousands of years ago when a Lake Michigan-sized glacial lake slowly evaporated. According to geologists, Lake Bonneville used to be 1,000 feet deep. Now, this extreme western corner of Utah is mostly dry, except after a rare rain when a thin pool of water covers the salt pan. But the moisture doesn't survive long. Under the high desert sun it evaporates rapidly, leaving the playa as flat and smooth as a flour tortilla.

Early on, Bonneville's unique pair of qualities — its flatness and its expansiveness — made it the place to test the absolute speed of wheeled land vehicles. Now, amateur carmakers from all over the world come several times a year, pushing their vehicles to incredible speeds in attempts to break records.

Fastest Wheels on Earth

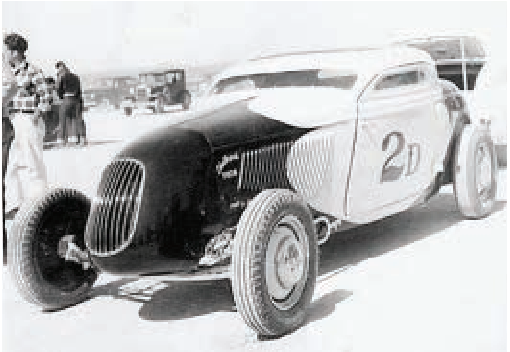
The greatest annual gathering at Bonneville is Speed Week. The event takes place in August when the salt is likely to be at its driest, hardest, and flattest. The Southern California Timing Association (SCTA), which organizes Speed Week, sanctions Bonneville attempts at land speed racing records. Vehicles range widely, from missile-like vehicles called streamliners to vintage, pre-1939 open roadsters.

Currently, the fastest speed on SCTA's record books for a piston-powered vehicle is 417mph, turned in by a methanol-burning, supercharged vehicle called *Burkland's Streamliner*.

Land speed racing is a different animal than drag or sprint racing. Land speed racers don't race against one another. They race against the speedometer.

Photograph by William Gurstelle

Attained: >132mph



OLD SCHOOL (1946): (top) Road Runners member Bill Burke's Belly Tank Lakester. This is the first belly tank lakester ever built. The world famous Pierson Brothers (Bob and Dick) 2D '34 coupe.

Photography by Al Baker, courtesy of bakerracingpix.com

The more creative the hot rodder, and the better his ability to handle complex fabrication operations, the faster his car.

Unlike drag racers, whose object is to turn in the fastest quarter mile, land speed racers focus on one thing alone — *maximum speed attained*. Terminal velocity trumps peak acceleration; quickness and handling take a backseat to horsepower and traction.

Drivers race in dozens of categories during Speed Week. Perhaps the most interesting is "special construction machines."

This category includes the lakesters and streamliners, and nearly anything goes. Vehicles can be powered by anything from electric motors to steam engines, although most are powered by piston engines burning gasoline, methanol, or nitromethane. Built from scratch specifically to run fast and straight on the dry lake beds of the American West, they epitomize straightaway racing.

Every lakester and streamliner driver's objective is to reach the highest speed possible. Setting records is what drives these people to drive fast.

The First Lakester

Beginning in the 1930s, many young men, especially in Southern California, spent every extra dollar they had working on their cars. Money was often tight, necessitating a great deal of ingenuity to get what the hot rodders wanted.

What they wanted was speed. The more creative the hot rodder, and the better his ability to handle complex fabrication operations, the faster his car.

During World War II, Bill Burke, an American sailor in the South Pacific, noticed a group of men unloading airplane drop tanks from a freighter. A drop tank was a large, teardrop-shaped fuel tank that was strapped to the belly of military aircraft to increase their cruising range. After Burke watched for a while, a light bulb switched on: this streamlined, aerodynamically shaped vessel would make a great body for a land speed racer.

After the war, Burke found he could pick up a war-surplus tank for as little as $35. He experimented with different tanks and soon focused on the 315-gallon tank that was originally slung beneath the twin-engine, twin-tailed P-38 Lightning.

Burke's first belly tank "lakester" reached a speed of nearly 132mph. Such speed from something as eye-catching as a fighter plane belly tank caught the attention of other hot rodders. Roaring across the Bonneville Salt Flats, belly tank lakesters soon became land speed racing's iconic image.

Going for a New Record

Gary Calvert (pictured at far left) of Enumclaw, Wash., is the spry, 69-year-old driver for Anderson & Calvert Racing. Calvert, partner Kirk Anderson, and helpers built their 204mph-capable vehicle from a football-shaped airplane fuel tank. Calvert's goal is to set a speed record for his type of belly tanker, known as a "blown gas lakester."

Blown means it has a supercharger that blows pressurized air into the engine intake manifold, thereby increasing horsepower and speed. *Gas* means its carefully rebuilt six-cylinder engine, repurposed from a Ford Taurus sedan, uses high-octane gasoline rather than nitromethane or other exotic fuels. And *lakester* signifies the classic open-wheeled design; made for running on dry lake beds, the car's wheels aren't covered by any wind-deflecting fairing or cowling.

THE NEED FOR SPEED: Steve DiMartino, in full regalia and ready to race. He built *Jesse's Girl* solely to push the pedal to the metal and take a chance at setting a speed record.

"When I first saw a belly tanker race," recalls Calvert, "I immediately decided that I wanted to make one myself. I found a surplus aluminum airplane belly tank in a scrap yard in Ogden, Utah, in 1988 and bought it for $175. All told, I spent about $14,000 on the racer. I imagine that it would cost more than $30,000 for me to build it today, plus all my labor."

Steve DiMartino (pictured above), another racer, has a day job working on Hondas, Toyotas, and Subarus at his shop in Lexington, Ky. For fun and excitement he hauls his belly tank lakester, called *Jesse's Girl*, nearly 1,800 miles to Bonneville. Why? DiMartino is a guy who loves to go fast.

"I came out to Bonneville in 1998 and I saw a belly tanker," says DiMartino. "As soon as I saw it, I said to my friend Jesse Connor, 'We ought to make one of those.'

"I went on a visit to Posies, a famous hot rod shop in Pennsylvania. Two belly tanks were lying in back there. I bought one of them for $400. From what I can tell, I think it came from a B-57 Canberra [a Cold War-era jet bomber]. We cut it in half and then figured out where to put all the bars [that form the vehicle's internal frame]. I work on Japanese cars, so my son picked a Honda S2000 engine for it. That's a stock, four-cylinder, two-liter engine. We used wind tunnel testing to make it perform better on the salt."

Early on Thursday morning of Speed Week 2008, DiMartino straps himself into the cockpit of *Jesse's Girl*. The teardrop-shaped, silver and orange belly tanker falls in queue behind a couple of Ford coupes, a nitro-powered streamliner, and an open-topped roadster. The driver and his son wait patiently for their time on the shorter, three-mile course to make a run at a record in the unblown gas lakester class.

In a previous run, DiMartino attained 201mph. This time he's shooting for a record-setting 215mph. The starter signals him. His son's truck gives the lakester a push start on the salt. The four cylinders kick in, the engine roars, and the car streaks off.

In an instant, the belly tanker is a receding dot on the salt flat. Seconds later, he's out of sight. The PA system crackles out the lakester's speed: "188.699 miles per hour."

Not a record, not today. But really, it's all about the effort, not the result. And it gives a builder like DiMartino something to work on tomorrow.

William Gurstelle is a contributing editor at MAKE and the author of several books. He lives in Minneapolis, Minn.

Photograph by William Gurstelle

Doing Da Vinci

A new series on the Discovery Channel puts the inventions of perhaps the greatest of all makers to the test.

By Jeanne Storck

BLADES OF GLORY: The *Doing Da Vinci* team fine-tunes the scythe chariot, a deadly war machine built to shred the enemy.

In an empty lot near a business park just outside Los Angeles, a group of men clusters round a phalanx of breech-loading cannons. Explosions rock the ground. A war reenactment? Not quite.

A crew of special effects engineers, welders, and carpenters are testing a series of full-scale Leonardo da Vinci inventions they've built for Discovery Channel's *Doing Da Vinci*. We spoke with a few members of the team, including da Vinci expert Dr. Jonathan Pevsner, movie engineer Jurgen Heimann, and builder/artist Flash Hopkins.

Jeanne Storck: Which inventions are you building?
Dr. Jonathan Pevsner: His machine gun, self-propelled cart, catapult, siege tower, and tank.

JS: Where do you begin?
JP: I show them the drawings from Leonardo's manuscripts and they ask questions: How big was it? How did the gearing work? What materials would he have used? What was its purpose?
Jurgen Heimann: I'm given the da Vinci artwork and I draw it in Inventor [design software], building it up part by part. Once it's built, I break down all the parts and export them as blueprint drawings to distribute to the team.

JS: What tools are you using?
JH: For the metalwork, we send stuff out to a company that can blast the part out using a water jet cutter.
Flash Hopkins: For the wood, we're doing this da Vinci style — handsaw, hammer, chisel, and table saw.

JS: How do you determine scale?
JP: Leonardo's designs often don't include a scale. Sometimes you can see a person or a horse nearby. For the siege tower, the team asked: "How wide was a moat in Leonardo's time?" I suggested 25 feet. If the moat were wider, it wouldn't be practical to build and maintain. If it were narrower, it wouldn't be effective. We have an idea of scale, and beyond that it often involves some interpretation.

JS: Any troubles interpreting the designs?
JH: With the tank, da Vinci designed this gearing system that links the wheels that drive it. On one of them he's got the gear on the wrong side, so you spin the drive shaft and now the two wheels that are connected are going in the opposite direction.
JP: Leonardo's designs sometimes include mistakes we believe were intentional — typical in the days before patents. If the drawings were stolen, it would be a bit harder for them to be implemented.
JH: His design for the cart shows three pictures and none of them are the same machine. They're variations on a theme, like he was coming up with ideas. So which design do we follow?

JS: Strongest impressions?
FH: The machine gun has 3 racks. Each rack has 11 cannons. Each cannon has a 4-inch breech and takes a 5-pound cannonball and 1 pound of powder. Each rack fires 11 cannons at once. It's earth-shattering.
JP: The tank looks like a spaceship scurrying along the ground. If I were an enemy infantryman and I was going to attack this tank, it would be really scary to see it for the first time, especially in the 15th century. I would want this guy Leonardo on my side.

Jeanne Storck is a freelance writer and interaction designer in San Francisco.

Photograph by Michael Becker

Worst-Case Internet

The Network Relief Kit brings online connectivity to disaster sites. By Mike Outmesguine

Communications is often the first service to go down after a disaster, assuming the area even has a connected infrastructure to begin with. Cellphones, EVDO, DSL/cable internet, and even land lines go down quickly when exposed to water or faced with power outages and broken fiber lines. But you can always count on the sun, a battery, and a satellite orbiting 22,000 miles high.

The backpack-portable Network Relief Kit (NRK) from NetHope does just that. Utilizing solar-electric battery charging and low-power satellite hardware, the $3,500 NRK brings together all the technology needed for a quick uplink to the outside world. It features a selection of easy-to-configure appliances designed to get field workers up and running quickly and easily with email, voice, video, and internet at very usable speeds.

The NRK relies on the Inmarsat Broadband Global Area Network (BGAN) satellite service, which is marketed toward the extreme business traveler dealing with disconnected parts of the world.

The BGAN connection requires a laptop-sized satellite terminal. Service costs around $1 a minute for regular voice calls and $3 to $6 per megabyte of data, plus monthly or annual subscription fees. Data speeds are up to 492kbps send and receive, and the service supports IP streaming up to 256kbps, making adequate-quality video possible.

BGAN satellite signals cover most of the globe, via three geostationary Inmarsat-4 satellites positioned over the equator: the I-4 Asia-Pacific over the West Pacific off Indonesia, the I-4 EMEA (Europe, Middle East, Africa) over the Congo, and the newly deployed I-4 Americas over the East Pacific near the

BACKPACK BROADBAND: The NRK includes all the necessary equipment for quick field deployment, and fits in a backpack or small suitcase.

Main components include:
1. **Inmarsat BGAN satellite terminal**
2. **Fold-flat 48-watt solar power kit**
3. **Small, lightweight laptop computer**
4. **8-hour battery power supply**
5. **Carrying case or backpack**
6. **Various phone, network, and USB cables, power adapters, chargers, and controllers to bring it all together.**

Also recommended: **Wi-fi router, ruggedized laptop, analog phone (if not available where you're going)**

> You can always count on the sun, a battery, and a satellite orbiting 22,000 miles high.

Galapagos. Absent from proposed BGAN coverage are the Arctic and Antarctic regions, with coverage fading around the 70th parallels. Relief agencies working in the polar regions will have to rely on another service such as the faster but less portable VSAT satellite technology.

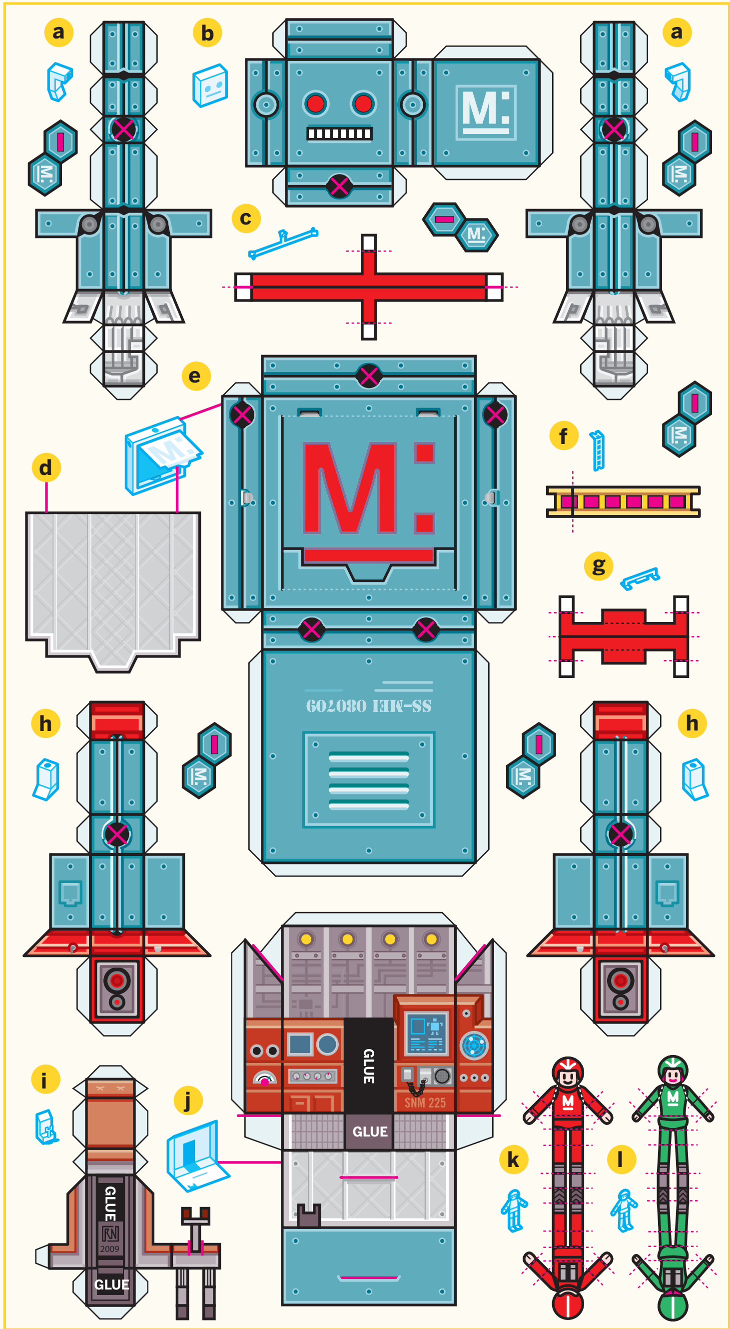
+ For more information, visit nethope.org.

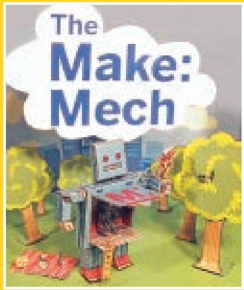
Mike Outmesguine is president and founder of TransStellar, Inc., a technology services company, and the author of *Wi-Fi Toys*.

Photograph by Kate Lacey

Make: ROBOTS

WARNING! Robots are running amok across the pages of MAKE. Be on the lookout for Makey, a sneaky little bot that sees obstacles and follows you around. Overhead, an autonomous flying drone could be snapping photos of you at this very moment. And beware of "toy" robots with high-tech brains hidden inside. **WARNING!**





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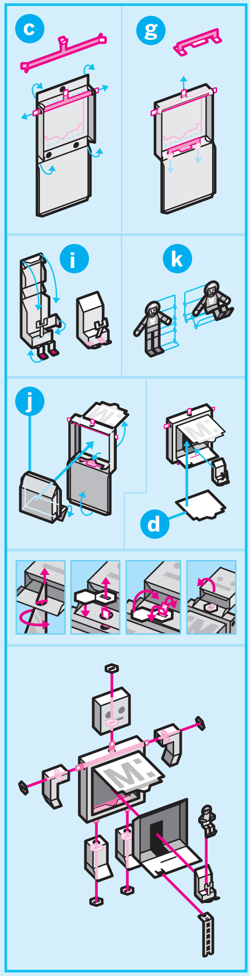


+ DOWNLOAD THE PDF, PRINT OUT ON CARDSTOCK, AND MAKE THIS RAD ROBOT! makezine.com/19/makemech

ILLUSTRATION BY ROB NANCE

A DRONE OF YOUR OWN

Build the world's cheapest, easiest to hack, and funnest autopilot.

BY CHRIS ANDERSON

A

Robots are cool. Airplanes are cool. Putting them together? Twice as cool. That, in a nutshell, is the inspiration for ArduPilot, our project to create the world's cheapest, easiest to hack and, dare we say, funnest autopilot. Add it to a standard hobby radio control plane, toss in a wireless video camera and transmitter, and you've got the makings of a pretty decent unmanned aerial vehicle (UAV).

When you hear UAV, you probably think military: the Predators or Global Hawks used in Iraq and Afghanistan, or the Navy ScanEagle used to look for pirates off the coast of Somalia. But UAVs are increasingly used by civilians for science (from atmospheric sampling to multispectral ground imaging), search and rescue, and simple aerial photography. Indeed, some of the imagery in Google Earth was taken that way.

The main thing keeping UAVs from being used as much for peaceful purposes as they are for defense is that the FAA has strict rules for their use in U.S. airspace that make it difficult to get permission for commercial use. But if you're flying them as a hobbyist and follow the same guidelines that the FAA has set for R/C aircraft (stay below 400 feet, stay within unaided line of sight, and always have a pilot able to take control), you can fly UAVs under a "recreational" exemption.

Even if you can't do much remote sensing while staying within line of sight, a UAV is still a really fun way to explore three-dimensional robotics.

Photography by Noah Webb

It can even be useful for things such as "first-person view" flying, where you use video goggles and an onboard video camera and transmitter to simulate the experience of being in the plane while it's flying, something that can be so disorienting that an autopilot is often required to make it home safely.

From Lego to Arduino

My own autopilot obsession started as something to do with the kids that was fun both for them and for me. We had a Lego Mindstorms NXT robotics kit and someone had given us an R/C plane. After quickly realizing that that we were never going to be expert at either (and not seeing much point in just doing stuff that others had already done), I got the idea of combining them. Thus, the world's first Lego UAV, which was written up in MAKE, Volume 12.

My next UAV was built on the observation that almost everything you need for an autopilot system is already in a good smart phone: computer, GPS, 2-way wireless data, a camera, and even a 3-axis accelerometer. Just strap it to the bottom of a plane with a serial interface to the R/C system, and the plane now has a phone number, allowing it to send images and receive instructions in flight. We turned the autopilot into a free software app for Windows Mobile phones, which worked well enough as a proof of concept but was too hard to maintain as phones evolved.

Next I turned to embedded processors, starting with the venerable BASIC Stamp. This proved educational, and although I created a barely functioning autopilot, it mostly illuminated the limitations of the BASIC Stamp board (no floating point math!).

At this point Jordi Muñoz, a fellow UAV hobbyist, suggested the then-new open source Arduino platform. It was much more powerful than the BASIC Stamp, but even easier to use, thanks to the Arduino IDE and excellent libraries created by the community. And unlike BASIC Stamp, it was open source hardware as well as software, which meant we could design our own custom board based on the Arduino reference design. A few months later, in late 2008, ArduPilot was born as a working prototype.

Creating an Autopilot Board

ArduPilot's hardware design started with the standard Arduino schematic (see arduino.cc), which we modified to add autopilot-specific features.

The first change was the easiest: we added a connector for a GPS module (we chose the EM-406, which is based on the excellent SiRF Star III chipset, which we knew well and had found to be rock-solid), and wired it up to the Arduino serial-in line.

B

Fig. A: Jordi Muñoz (left) and Chris Anderson (right) have developed a kit to turn ordinary remote control planes into autonomous flying drones. Fig. B: Muñoz prepares to launch an autonomous drone.

Then we added the ability to interface with R/C equipment. Arduino has the built-in ability to read and write pulse-width modulation (PWM) signals, the standard used to control servos in R/C gear, on its digital pins. But we wanted to do more than just add standard 3-pin servo connectors to the board. Instead, we felt that the ability to regain manual control at any time in case of autopilot failure was so important that we should create a special circuit that did it in hardware, rather than trusting software (which could crash) to do it.

Some people choose to handle the fail-safe function in software, using interrupts to check to see if the autopilot code is still running properly and switching to manual control if not. For closed source projects, where you can rigorously test and control the code, this may be a good solution. But for our open source project, where we didn't know what people would be doing with our code and what sort of bugs they might introduce, we thought it was safer to make this a standalone circuit.

Our fail-safe circuit consists of 2 elements: a multiplexer chip that switches outputs between

Unmanned aerial vehicles are a fun way to explore three-dimensional robotics.

2 inputs, and an ATtiny microprocessor (the little brother of the ATmega chip at the heart of Arduino), which reads the output from one R/C channel that serves as the autopilot control channel and controls the multiplexer. When you toggle up one of the switches on your R/C transmitter, the circuit transfers the servos plugged into ArduPilot from R/C to computer control, and back again when you flick the switch down. This circuit can also read intermediate positions if you have a dial on your R/C transmitter, and ArduPilot can assign those positions to other modes like computer-assisted flight, which stabilizes the plane under manual control.

Although the board is normally powered by the R/C system at the standard 5V, we also added a standalone power regulator for people who want to power it independently with its own battery.

That's pretty much it for the new hardware elements. Jordi laid out the board to be super small (about the size of a 9V battery) and routed the wires to minimize their length to avoid noise. With the help of Nathan Seidle at SparkFun Electronics, we turned unused parts of the board into "ground planes," extending the copper traces into large areas that help reduce RF noise.

Now it was time to make the boards. For prototypes, the usual way is to send the PCB design files (we used the free CadSoft EAGLE program) to a fab. We used BatchPCB, SparkFun's own service. When we got the boards back, we hand-soldered the chips (they're surface mount, so it was a fiddly process and we messed up one or two boards) and went through revisions until it worked the way we wanted.

Then we gave the green light for SparkFun to manufacture them, which in practice means that their pick-and-place robot puts the chips precisely on the boards and they're soldered in a reflow oven.

Writing the Software

One of the deceptive things about autopilots is that they look like a hardware project. After all, what more do you need to do than read some sensors and a GPS module and move servos to keep the plane flying level and on target? But as anyone who has tried it quickly discovers, the hardware is the easiest part of an autopilot. The software is where the real challenge lies.

There are two main functions to an autopilot: stabilization (keep the plane flying level) and navigation (fly to designated waypoints or "loiter" by circling designated spots).

Stabilization is a classic control systems task, involving PID (proportional, integral, and derivative) loops, which have to be tuned for each aircraft, and sensors (gyros, accelerometers, or infrared horizon sensors) that are each imperfect in their own way.

Navigation is a bit easier, since you have absolute GPS data to steer by rather than sometimes uncertain orientation data, but to go efficiently from point A to B when the plane is being pushed sideways by the wind requires clever algorithms, too.

Initially, ArduPilot began as a GPS navigation-only autopilot, requiring a standalone commercial stabilization system such as the FMA Direct Co-Pilot to handle wing leveling. It also worked for 2D projects such as cars or boats that don't need stabilization; indeed, it was used by several of the autonomous rovers that competed in this year's SparkFun Autonomous Vehicle Competition.

We then upgraded ArduPilot with version 2.0 to handle the stabilization function itself, using special arrays of IR sensors called "thermopiles" that detect the differential in heat signature between the earth and the sky. Infrared stabilization is easier and cheaper than using a full array of at least 3 gyroscopes and 3 accelerometers, as are used in the inertial measurement unit (IMU) in higher-end autopilots (we'll move to that with a future version of ArduPilot).

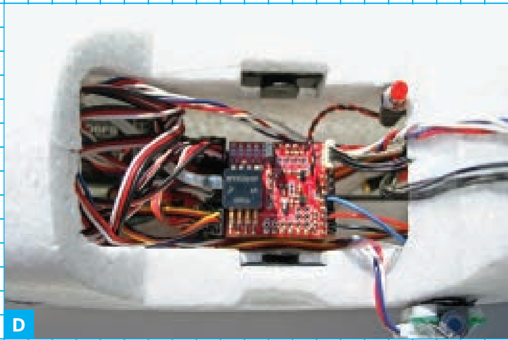
Modern GPS modules give pretty good altitude data (plus or minus a few meters, if you average the data to remove outlier glitches), but to properly control a UAV in the wind you need more than the speed-over-ground velocity data that a GPS module generates.

What's far more important is airspeed, and the only good way to calculate that is with a differential pressure sensor, which is really a pair of sensors: one is attached to a pitot tube in the nose or wing of the aircraft where air is forced into it by the forward motion of the plane, while the other measures ambient pressure in the cockpit.

In testing ArduPilot with a powered glider (the Multiplex EasyStar) we realized that without an

Photography by Jon Snyder

C



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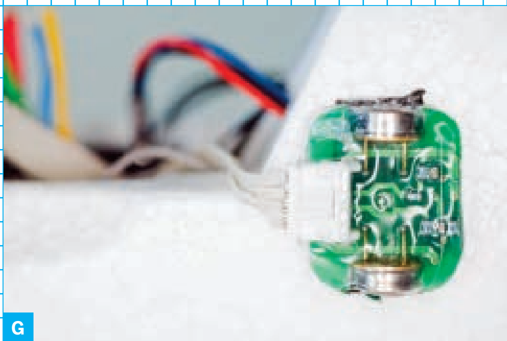

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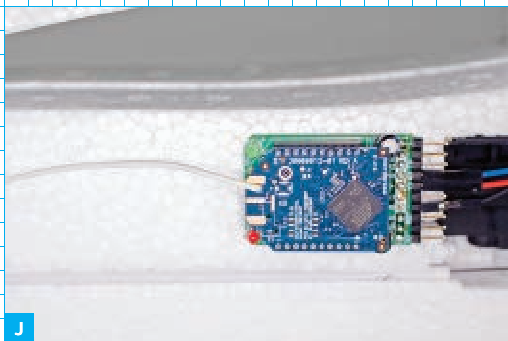

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ANATOMY OF AN UNMANNED AERIAL VEHICLE: Fig. C: The assembled DIY Drone. The parts to build one cost about $300. Fig. D: The ArduPilot autopilot system is based on the Arduino open source hardware platform. Fig. E: The GPS module used for navigation. Fig. F: XY sensor for stabilization. Fig. G: Z sensor for stabilization. Fig. H: Z sensor and servo mounted on UAV. Fig. I: Digital camera and XBee wireless module (for real-time wireless telemetry). Fig. J: Close-up of XBee telemetry system.

We put ArduPilot 2.1 to the ultimate test: the SparkFun Autonomous Vehicle Competition.

airspeed sensor and throttle control, wind would be a serious problem. Going downwind was fine, but heading into a strong wind at constant medium throttle the plane often came to a standstill as measured by ground velocity.

Not only was the plane not making headway, the GPS module was giving random data for its direction vector, since it wasn't moving forward from reading to reading (one per second with the EM-406). An airspeed sensor would detect that the plane was moving relative to the air (or rather, the air was moving relative to the plane) even though it wasn't moving relative to the ground, and would increase the throttle to make headway.

This required us to design an expansion board for ArduPilot. In the Arduino world, such expansion boards are called "shields" (because they fit over and cover the main board). Our shield includes the differential pressure sensor, a 3.3V power regulator so people can add 3.3V sensors or switch to a faster GPS module (most of the 5Hz GPS modules run at 3.3V), connectors to make attaching sensors easier, and other circuitry to make field operation simpler.

Finally, Jordi designed desktop software to make it easier to configure ArduPilot and monitor it in operation. Earlier versions required users to go into the code itself to add and change waypoints; the desktop configuration utility makes this an easy, point-and-click-on-a-map process.

Jordi also designed a ground station to monitor a UAV in flight. ArduPilot is designed to allow you to easily add wireless telemetry by connecting an XBee wireless module to the autopilot and match it with another XBee module on the ground. The autopilot sends information about its attitude (roll, pitch, and heading) as well as GPS coordinates, altitude, waypoint number, and other status, which is displayed in real time on dials and a moving map (through Google Earth) by the ground station software.

In April, we put this version, ArduPilot 2.1, to the ultimate test: the SparkFun Autonomous Vehicle Competition. As Mark Frauenfelder reports on page 72, neither wind nor trees could stop it (although we would have been sunk without the Boulder Fire Department). Our ArduPilot-powered UAV won, circling the SparkFun building in 36 seconds.

What's Next

Today, SparkFun has sold about 600 ArduPilot boards, and our community site, DIY Drones, has around 5,000 active members — both numbers are growing fast. We're working on the next version of ArduPilot, which will be built on the new Arduino Mega platform (lots more I/O pins and serial ports) and will probably have a full IMU.

An on-screen display that puts telemetry and other data into a real-time video stream is in the works, and we're testing the autopilot on different aircraft, from speedy FunJets to docile trainers that can carry large loads.

Meanwhile the community is finding all sorts of new ways to use and extend ArduPilot, from cars and boats to experiments with helicopters, quadcopters, and even high-altitude balloons. All it took was one little board and the magic of open source. Now thousands of people are exploring a new dimension of robotics — up!

What You Need to Get Started:

» **ArduPilot from SparkFun Electronics (sparkfun.com), $25**
» **EM-406 GPS module from SparkFun, $60**
» **Thermopile pitch/roll (XY) sensors: part #CPD4SENUNIT from FMA Direct (fmadirect.com), $43**
» **FTDI USB-to-serial adapter for programming, from SparkFun, $14**
» **Multiplex EasyStar plane from Tower Hobbies (towerhobbies.com), $60**
» **R/C equipment: transmitter, receiver, servos, etc. Any type will do.**

All instructions and code are at ardupilot.com. Follow us and the rest of the amateur UAV community at diydrones.com.

Chris Anderson is the editor-in-chief of *Wired* and the co-founder of the DIY Drones group (diydrones.com).

Photography by Noah Webb (N, O) and Jon Snyder (P)

N

O

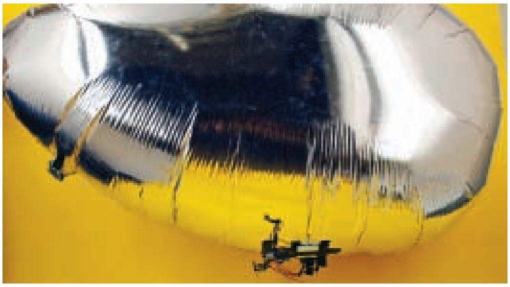
P

Fig. N: The UAV's mobile ground command center includes a laptop computer for course-plotting, a remote control, and a patch receiver antenna for telemetry. Fig. O: The UAV is launched by hand and is human-piloted until it reaches a sufficiently high elevation to allow control to be taken over by the autopilot. (Even when the drone is in autonomous mode the pilot on the ground can take over at any time.) Fig. P: The styrofoam body used here is a common R/C model plane, and can be easily disassembled and loaded into a car.

MEET THE BLIMPDUINO

Introducing a new kit to build the fastest, most nimble blimp around.

BY CHRIS ANDERSON



Want to try aerial robotics but aren't quite ready for a UAV? You might want to start with an autonomous blimp instead — they're a fun project for all ages and a real crowd-pleaser as they navigate slowly around a room detecting their surroundings and tilting their props to steer and hold altitude.

Blimps have a lot of advantages over planes. You use them indoors, so weather isn't an issue. When things go wrong, they don't hurt themselves or anything else, so they're safe for kids. They're an interesting autonomy challenge, in many ways harder than a plane, because GPS doesn't work indoors (so other navigation methods are required) and the motion of the blimp is dominated by huge inertial momentum, more like a submarine than an airplane. And they're simply lovely to watch, with a uniquely graceful, even whale-like motion through the air.

We got started with blimps with MAKE's Blubber Bot kit, an art piece created by Jed Berk that floats around with a mind of its own, reacting to light and noise. It was fun, but we wanted to take blimps to the next level, with programmable autonomy, navigation, and an option for manual radio control, along with a more sophisticated propulsion system that could control altitude.

As with our fixed-wing autopilot, we based our blimp on the Arduino open source hardware platform so people would be able to use its great cross-platform programming tools. We designed the blimp controller board, propulsion system, and sensor arrays from scratch, using our favorite prototyping tools, from Lego pieces and thin plywood sheets to small breadboards and micro Arduino modules.

With lots of trial and error we settled on a few core technologies. For altitude measurement, we use ultrasonic sensors (the MaxBotix EZ4). For navigation, we use an array of 4 infrared detectors and a ground-based infrared beacon. For propulsion, we use "vectoring differential thrusters," which is to say, 2 motors that can spin their propellers at different speeds (differential thrust) to turn the blimp right and left, and are mounted on a shaft that a servo tilts up and down (vectoring) for altitude control. For the mechanical assembly, we used a laser-cut plastic platform and stayed with Lego Technic parts for the shaft and gearing (thanks to a generous donation of a huge box of parts from Lego!).

Now Blimpduino is a commercial kit (available at makershed.com). It comes with most of what you need, save helium, batteries, and (optional) R/C equipment. All the tricky surface-mount soldering has been done for you, so the kit can be assembled by anyone with some simple tools in an afternoon.

What It Can Do

» Fly incredibly well in R/C mode. This is the fastest, most nimble blimp around, thanks to the awesome vectoring thrusters (much better than using a third motor for up/down motion, as most toy blimps do).

» In autonomous mode, it will fly patterns around the ground-based beacon by default, or follow the beacon if you carry it around, maintaining altitude all the way. But it's possible to do more than that: you can use multiple beacons and program the blimp to travel from one to the next, which will allow it to do simple courses, and you can also program it to change altitude in relation to a beacon (descending as it approaches it, for example).

What's next? We're hoping people will fall in love with these autonomous blimps as we have, and that they'll introduce a generation of future engineers to aerial robotics. This year Blimpduino was demonstrated at the FIRST Robotics annual championship, and we hope next year it will be the basis of a demonstration 3D robotics competition for college students as part of the FIRST program. With everything from blimp sumo wrestling in R/C mode (push the opponent out of a marked-off column area) to autonomous maze racing, this competition will be a blast, adding a vertical dimension and the unique challenges of motion through that most abundant of fluids, air. Blimps are, simply, a robotic delight.

Photograph by Sam Murphy

DRONES OF YESTERYEAR

Reconnoitering the UAV exhibition at the National Air and Space Museum.

BY MARC DE VINCK

You might think unmanned aerial vehicles, or UAVs, are a recent technological breakthrough. But this really isn't the case.

According to the Smithsonian Institution, one of the earliest UAVs was developed during World War I and was essentially a small pilotless biplane that was able to deliver its payload more than 50 miles away.

This amazing piece of technology, known as the Kettering Aerial Torpedo or the Kettering Bug, was developed in 1918 by Charles Kettering for the U.S. Army. A rudimentary gyroscope — along with a pneumatic/vacuum control system and a mechanical distance counter — guided this ancestor of the cruise missile to its intended target ... with any luck.

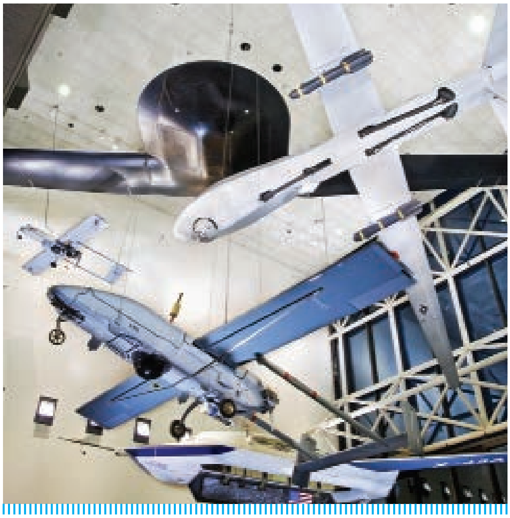
It wasn't until the 1950s and 60s that these vehicles became more than just guided bombs. The addition of radio controls allowed for the recovery of UAVs. This dramatically changed the way they were used by the military: now they could be used for reconnaissance and data gathering, not just as disposable weapons of war.

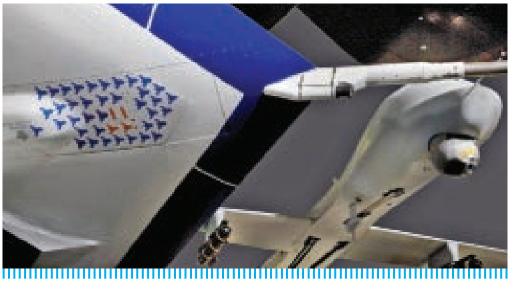
The National Air and Space Museum (NASM) on the National Mall in Washington, D.C., has several UAVs on display, all hung from the ceiling in typical Air & Space fashion. This allows visitors to view them from above and below, gaining an interesting perspective of these fascinating machines. The exhibit ranges from the small and versatile Dragon Eye reconnaissance mini-UAV at just over 3 feet across, to the massive DarkStar, which spans a full 69 feet!

Walking into the exhibit, it's hard not to notice the MQ-1L Predator A, built by General Atomics Aeronautical Systems. The Predator is one of the most recognizable UAVs since it has played a major role in both Iraq and Afghanistan. The one on display flew more than 196 missions in Afghanistan.

The UFO-looking RQ-3A DarkStar, built by Lockheed Martin and Boeing, first took flight in 1996 but crashed a month later during its second test flight. Two years later a second prototype proved successful, but in 1999 the project was cancelled, making this example on display extremely rare.

Photography courtesy of the Smithsonian Institution





The NASM's Military UAV exhibit includes the MQ-1L Predator A, RQ-3A DarkStar, RQ-14A Dragon Eye, RQ-2A Pioneer, RQ-7A Shadow 200, and the X-45A.

The UAV exhibit, while fascinating in its own right, is just one of many reasons to visit to the National Air and Space Museum. From the *Spirit of St. Louis* to the *Enola Gay* and the space shuttle *Enterprise*, the aeronautical treasures housed here will leave you awestruck.

+ National Air and Space Museum UAV exhibit: makezine.com/go/nasm

Marc de Vinck is the product curator and evangelist for Maker Shed (makershed.com).

BOT STATE OF THE ART

Robot engineers and enthusiasts discuss what's currently holding their attention.

BY GARETH BRANWYN

To gather thumbnail sketches of what's going on in amateur and professional robotics, we asked some of our favorite robot builders, suppliers, and researchers a simple question: What's the most exciting thing for you in robotics right now? Here's what they had to say.

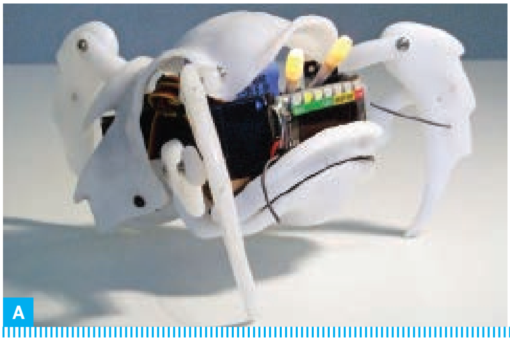


Fig. A: Crabfu SteamWorks' characterful Swashbots are designed to elicit an emotional response.
Fig. B: Dean Goedde's AttoPilot turns almost any R/C model plane into an unmanned aerial vehicle (UAV).

I-Wei Huang **Crabfu SteamWorks, creator of steam-powered and radio-controlled robots and walking and flying machines (crabfu.com)**

What I love most about building robots is trying to achieve a hint of the illusion of life. I try and make people feel something for a heap of hardware. The easiest and fastest way to do this is with humor. That's why most of my contraptions are cute, wonky, odd, with no real purpose except to (hopefully) make people smile.

Recent developments in robotics show machines getting more fluid, organic in their motions. But I think more effort should be devoted to this art of illusion. I've been awarded five medals at RoboGames, and received several golds for Best of Show, with very simple contraptions. They won out against much more sophisticated robots because they conveyed a characterful impression that stuck with the audience (and the judges). They're laughable, literally. And people respond to that.

Ken Gracey **Vice president of microcontroller and robot kit manufacturer Parallax, Inc. (parallax.com)**

Without a doubt, the state of the art in robotics right now is Dean Goedde's AttoPilot (attopilot.com). We've all seen lots of hobby and educational autopilot variants, but this one is based on complete scientific integration of all sensors into PID control loops (see makezine.com/go/pid). As a scientist from Intel, Goedde has taken the right approach with this product, starting from the mapping of Google Earth coordinates, to the storage of this data on an SD card, to the plugin for his AttoPilot.

There's a reason all the right people are talking to Goedde about this product. When he throws an airplane up into the sky and turns off its transmitter, you really understand the importance of this achievement.

Mark Tilden **Inventor of BEAM robotics, creator of Robosapien, and robot designer for WowWee (wowwee.com)**

For me, the coolest thing in robotics currently is inexpensive gearboxes and servos. They've allowed a whole generation of Robo-One (robo-one.com) Frankensteins to quickly evolve into affordable, sophisticated humanoids created for the sole

purpose of beating the crap out of each other.

Modern sensors are now accessible too — brains are still the cost-complexity stumble for Turing competence, so it's great that the AI community has finally decided "emotion" is not a dirty word, so we can explore bots with feelings.

I have to give a shout-out to Festo (festo.com) for showing that robots can be things of wonder and grace, to my JPL homies for keeping their little red Mars wagons roaming well past their warranty, Theo Jansen (strandbeest.com), steampunk, solarbotics.com, Pixar, and Japanese robo-culture, but mostly, to anyone who recognizes the electric screwdriver as their prime weapon of exploration and mischief. (And on that note, it's been 21 years since BEAM robotics was invented, so take your Robosapien out for a drink. He's legal now!)

Matt Trossen CEO of hobby and educational robotics vendor Trossen Robotics (trossenrobotics.com)

Here at Trossen, we get a more street-level view of things than a mainstream retail view. From a big commercial perspective, one might think that the robotics industry is in trouble.

In the last six months we've seen prominent robotics products stall or fail: Ugobe, maker of Pleo, filed for bankruptcy; Tomy discontinued the i-Sobot; Roomba seems to have peaked and everyone is waiting for a successor. We don't see any of this as real commentary on the state of robotics. Blips on the consumer radar are common when early adopter companies gamble at putting bleeding-edge technology on store shelves.

To us, the heart and soul of robotic innovation is alive and kicking. We see it every day, in research labs, robotics small business products, academic competitions, and especially, in the garages and basements of independent innovators. While retail robotics might be falling victim to a stalling economy, those "on the street" are hard at work, inventing, experimenting, and learning about the next great technology that will likely change human society in the same way that the industrial and computer ages did.

Fig. C: Online videos of Festo's AirPenguin went viral among robot enthusiasts, thanks to its seemingly effortless, fluid movements (see makezine.com/go/penguin). Fig. D: Robosapien comes of age.

Grassroots innovation is showcased daily on our forums from builders across the globe. Some examples:

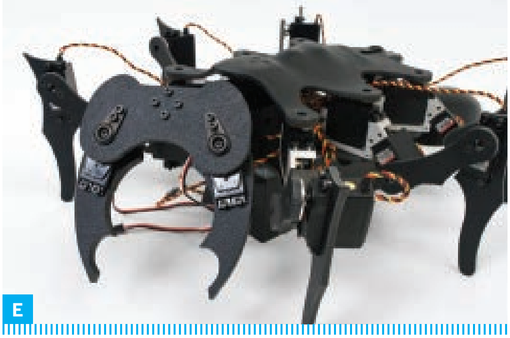
» Kare Halvorsen in Norway has created amazingly advanced inverse kinematics with his Phoenix and A-Pod hexapods, which exhibit amazingly lifelike movements. Usually this level of motion control is only found in heavily funded research projects, but Halvorsen's work is now accessible to anyone in the amateur community and available in pro-hobbyist kits.

» Our very own Andrew Alter has been working nights and weekends on his Hagetaka Mech robot for competition in Mech Warfare at this year's RoboGames. Wireless control with a video feed to headset goggles; dynamic, kinematic-driven bipedal gaits using 7-degrees-of-freedom, reverse-knee-joint legs; auto-balancing using a 6-axis balance sensor; and dual airsoft guns are just a few of its features. It stands 27" high and its servos are strong enough to carry 4 pounds of payload, which is a lot (for those who may not know).

Simone Davalos Co-producer of RoboGames (robogames.net) and lead editor at Suicide Bots (suicidebots.com)

In my field of recreational robotics, robots don't necessarily perform brain surgery or provide award-winning customer service. These are bots that just about anyone can build, just for the fun of it.

The most amazing thing I see is the amount of



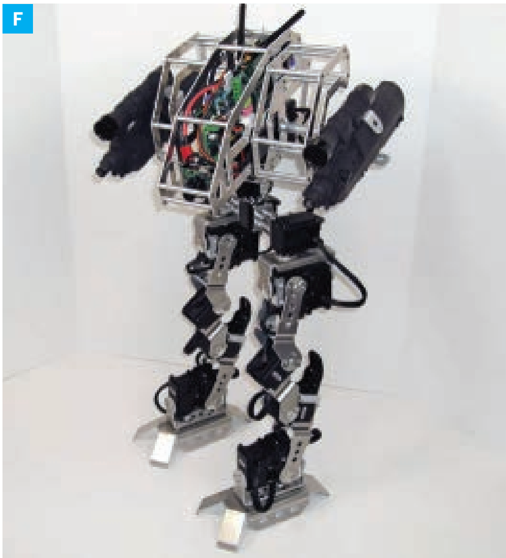


Fig. E: Kare Halvorsen's extraordinarily lifelike hexapod robot. Fig. F: Trossen Robotics employee Andrew Alter's Hagetaka Mech robot. Fig. G: Sparks fly and robots die at the annual RoboGames.

increasing access that's available to know-how, components, and materials. Before, a potential robot builder needed to be affiliated with a university or other research body to get their project off the ground. Now, all a person needs is an idea and a net connection.

Even shop space is now readily available in many areas through hacker spaces (such as Noisebridge in San Francisco and NYC Resistor in New York City), DIY centers like TechShop, and art and technology collectives (like the Flaming Lotus Girls in San Francisco). These places are tremendously open, anyone can join, and people are usually willing to show what they know to beginners.

David Calkins Co-producer of RoboGames, robotics instructor at San Francisco State University, and president of the Robotics Society of America

I think the coolest thing happening in robotics is walking robots — humanoids. They aren't the most practical, by any means, but if you ask a hundred people to draw a robot, you'll end up with mostly androids (C-3PO types). Wheeled robots are far and away more efficient, but R2-D2 will never be as "cool" as C-3PO.

When we do robot events like RoboGames, our fleet of 15" humanoids are the real showstoppers. They can do cartwheels, stand on their heads, play soccer, and have kung fu fights. Now we've added airsoft cannons for Mech Warfare, where human operators have to control their bots by POV cameras — the humans can't see the actual field of play.

Gordon McComb The "father of hobby robotics," author of the classic *Robot Builder's Bonanza*, and owner of Budget Robotics (budgetrobotics.com)

With costs going down, many more people are able to experiment in robotics. An example is the creation of "psych bots." In the 90s, there was intensive research into breaking down barriers between humans and machines. A new cadre of robots today are instead designed to improve human-to-human interaction. Many researchers have been inspired by Keepon (beatbots.net), an interactive device for studying social development in children, especially those with developmental disorders such as autism. By making robotics more affordable, this type of research is now in the hands of more experimenters.

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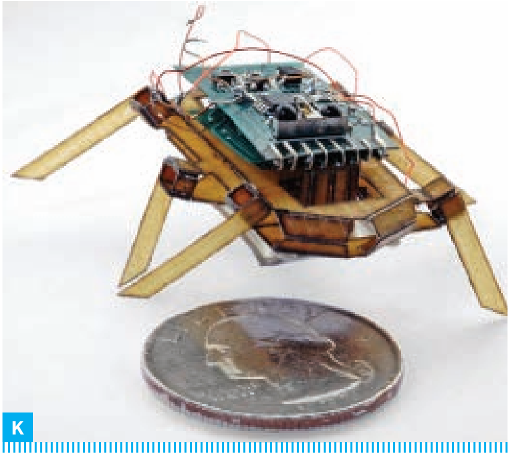

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Fig. H: Mini humanoid robots are coming into their own and always garner lots of attention at robot events. Fig. I: Robots, such as the Keepon, developed by cognitive scientist Hideki Kozima, are increasingly being used in therapeutic settings. Fig. J: Meet Christopher, Oomlout's Arduino-controlled crocheted alien/robot/business executive. Oomlout isn't sure what he is, except a lot of fun at parties. Fig. K: From the Biomimetic Millisystems Lab at UC Berkeley come rapid-prototyped, print-and-fold robots.

The Oomlout team **Makers of open source robot and microcontroller kits (oomlout.com)**

The coolest thing in robotics right now is ... fun! It sounds hokey, but for the first time, the mechanics, electronics, and programming tools required to make really amazing robots are available to just about anyone. No longer are robots forced to live out their days mindlessly assembling cars on factory floors or slavishly performing demos in university labs. Robots are moving onto our walls, our floors and countertops, and our balconies. They're making pretty pictures, entertaining us at parties, even twittering the "mood" of the tomato plants on our porch.

Are they doing these things because they're necessary? No. They're being put to these ends mainly in the interest of fun and exploration. We believe that from this atmosphere of frivolity, the serious robotic future we've long been promised will finally take shape.

Dave Hrynkiw **BEAM robotics guru and owner of Solarbotics.com**

Mobility. No more limp-motored rollerbots, although they have their place in particularly elegant solar-powered robots. We now have devices that balance (Segway), walk (Robo-One), and climb heavy terrain like a mule (BigDog). Two of these are consumer-available now, but wait for the Air Muscle geeks (makezine.com/go/muscle) to housebreak a version of BigDog. I remember $80 pager motors. Let the economies of scale keep working their magic, and we'll have Energon-powered bio-actuators in no time.

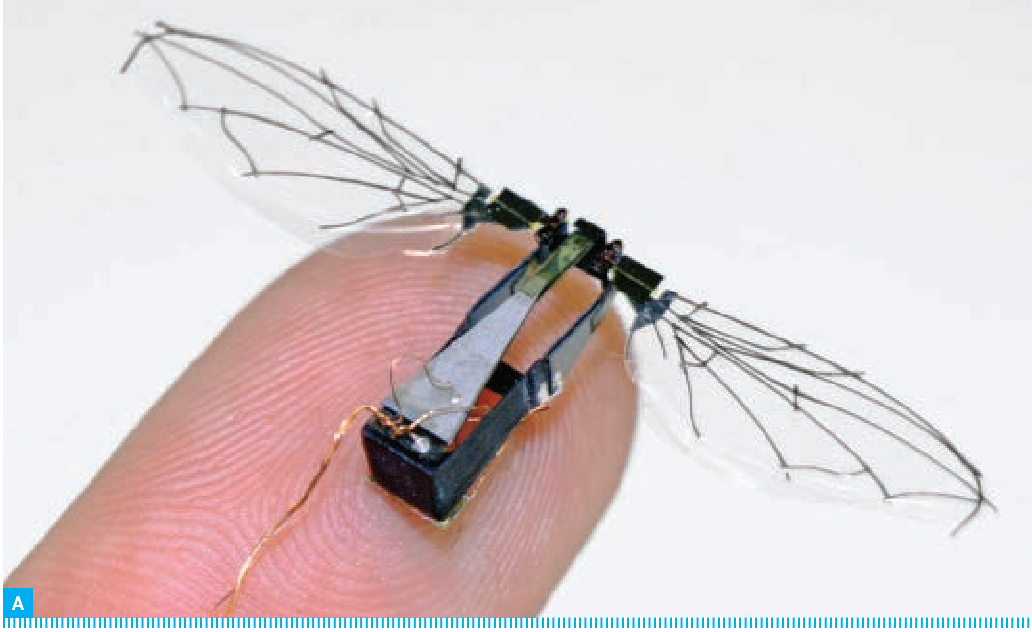
Oh, and also, two words: folded robots (makezine.com/go/folding).

Gareth Branwyn is a senior editor at MAKE.

PEST CONTROL

The director of the Harvard Microrobotics Lab builds a better housefly.

BY BOB PARKS



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It's tempting to see the first-ever flight of a robot insect as a kind of Kitty Hawk moment, clearing the way for all kinds of flying robots, sensor-packing drones, and surveillance bugs buzzing around our personal airspace.

The maiden voyage of the world's smallest flying robot occurred in March 2007, while researcher Robert Wood was pulling a late work session. The director of the Harvard Microrobotics Lab, Wood watched as his 60-milligram, 3-centimeter model rose a few centimeters off the workbench. It was fixed vertically by two stiff guide wires, and had hair-like power cords feeding it current. Images from the high-speed camera footage were broadcast around the world, and Wood earned top honors including *Technology Review* magazine's list of young innovators under 35.

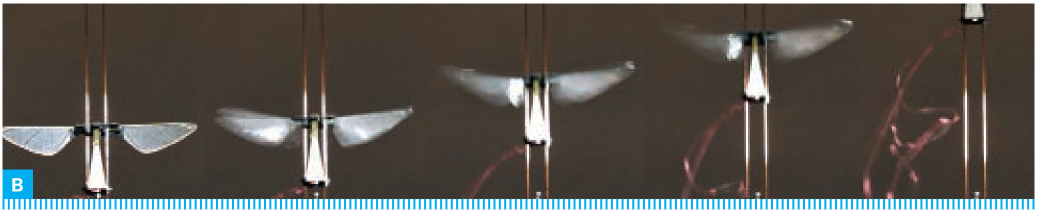
And yet, as interesting as the flying bug was, it diminishes Wood's more wide-ranging accomplishment — that he's making machines at this scale at all. Nestled in two small rooms on the Cambridge, Mass., campus, his team of 20 researchers has invented a whole new way of building complex mechanisms the size of a peanut. It's a process that involves laser-cutting thin sheets of carbon fiber into 2D patterns, then folding them with tweezers to create fully 3D mechanisms with moving levers, linkages, and power drives. The Lilliputian devices use electroactive materials and tiny power converters to create engines much more powerful than magnetic motors at this scale, even more powerful than a real housefly's thorax.

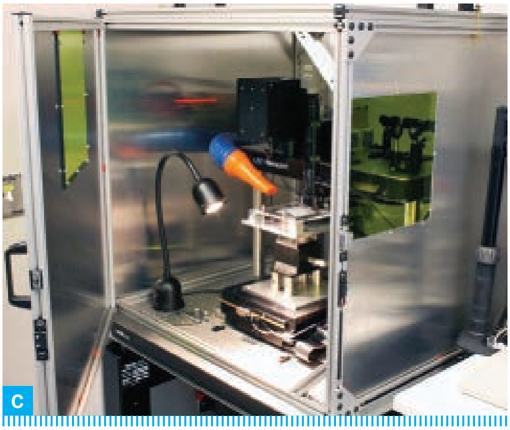
"When we started, we had all these fantastic ideas about what to do with a swarm of artificial flies," says Wood, recalling his first few weeks in grad school. "We wanted to test various designs, but in reality, nothing existed on this scale."

Wood, 32, is soft-spoken and spends his time hovering between the various workstations in the lab in a neatly ironed dress shirt, jeans, and Doc Martens.

He explains that other processes wouldn't work for his flies. Nanotechnology, which manipulates individual molecules, would produce objects too small

Photography by Ben Finio (A), Robert Wood (B), and J.P. Whitney (C)





SUPERFLY: Fig. A: Robert Wood's 3-centimeter microrobotic fly is powered by a piezoelectric material that pushes the wings via a hinged transmission. Fig. B: The fly in flight, tethered by its power wires. Fig. C: Photonics Industries laser micromachining system at Harvard Microrobotics Lab.

to use for his work. And microelectromechanical systems (MEMS), which print objects in a process similar to computer chip fabrication, would create parts too fragile and expensive. His system is cheap, simple, and getting faster. The team constructs new bugs from the ground up in less than two days.

Wood's process came out of new evidence about flying insects that arose in the late 1990s. As an electrical engineer at Berkeley, he entered grad school at a time when a biologist on campus named Michael Dickinson was performing groundbreaking experiments on fruit flies.

Researchers had long known that bugs live in a world in which the physics feels much different from our own. Dickinson proved that an insect's aerodynamic lift comes from little-known forces such as the leading edge vortex, little swirls and eddies generated by the front edge of its wings.

He used high-speed video to analyze the movements of flies making hairpin turns in the air, then he attempted to re-create the motion with an enormous fruit fly robot. To ensure that his model (with a 28-inch wingspan) obeyed the physics of scaling, Dickinson immersed the device in a vat of mineral oil. The experiment revealed several new sources of lift that the Wright Brothers had never dreamed of.

Wood and his fellow roboticists, under advisor Ron Fearing, often met with Dickinson's group, consulting on the oversized fruit fly, which got them all thinking about how to make a fly at true scale. "At first, the goals we had were mind-boggling," Wood says. "You couldn't use typical machining, like making ball bearings, because as you decrease the size of the bearing, its surface-area-to-volume ratio grows, friction takes over, and smooth surfaces start to grind instead of slide."

So Wood tried out a system of levers and flexure joints instead. He cut thin strips of carbon fiber with a laser and sandwiched them in flexible polymer strips to create hinges. By combining links and hinges, he created a bug "transmission" with a four-bar linkage, a common mechanism used in things like vise-grips and windshield wipers. In his bug, the linkage translates the speed and torque of an actuator into a flapping wing motion.

Then campus biologists gave Wood an additional challenge by informing him of the tremendous power in a housefly's thorax muscles — about 80 watts per kilogram. Because conventional motors and engines weren't applicable (the friction alone would stop a drive shaft), Wood experimented with a piezoelectric material called lead zirconate titanate, or PZT, which gets thicker and shorter when charged with electricity.

If you firmly glue the PZT ceramic to a substrate, it becomes constrained from changing size, and instead springs outward like a little diving board. He glued PZT strips to either side of a carbon fiber strip, and applied the necessary 200 volts to get the device moving. Switching the voltage from side to side makes the little diving board swing forcefully back and forth, at around 100 times a second — about the stroke cycle of a real fly.

Using this material, the robotics team was very close to matching a real fly's muscle power. Then they learned that the PZT holds on to part of the electric charge after its work is done. Wood's team designed a circuit to recover this energy and send it through the second PZT strip during the other

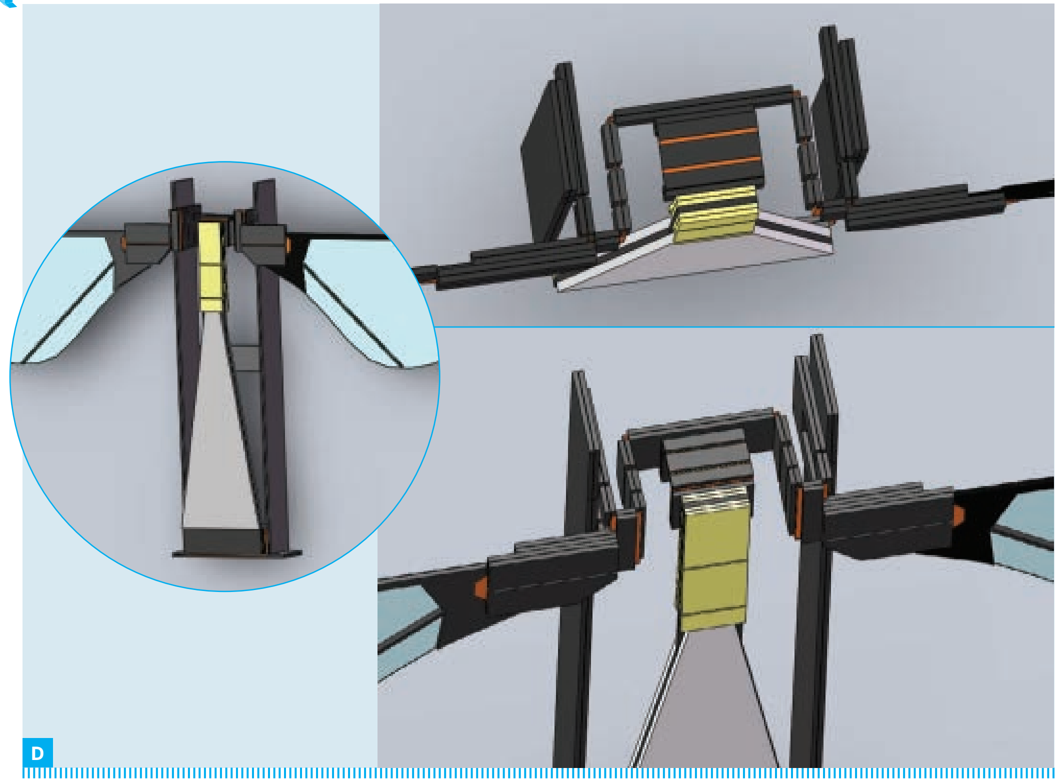


Fig. D: AC power from tether wires makes a piezo actuator push and pull the base of a flexible transmission, flapping wings attached at the top.

half-cycle, making the actuator many times more efficient. The actuator delivered more than 400 watts per kilogram — about five times the energy of a real bug's muscle, and enough to get the project literally off the ground. Using this technique, Wood succeeded with a flying robot one year after moving into his current lab at Harvard.

"The monkey's off our backs," he says, describing the tremendous pressure to show the world that his bug could fly, and the relief afterward. Now he's more clearly. There's no computer software that can conduct simulations for this scale. No one has modeled this world adequately, despite the experiments from biologists in the last decade.

One major unknown is the question of flex. The large fruit fly model used at Berkeley had stiff wings because the researchers wanted to limit their variables. But houseflies flap nearly horizontally to gain lift, flexing a little on the upstroke. (Wood demonstrates with the flat of his hand.) His housefly flexed its wings during each stroke, using hinge joints in the wings. Joint stops prevented overtwisting.

The way to answer the question of flex, as well as curvature, proportion, and a dozen other variables, is simply trial and error. "We're going to just start popping wings on and off to correlate design factors with real lift and drag forces," he says, proudly showing off a small black velvet stage with an expensive, high-speed videocamera capable of 10,000 frames per second. This setup will record highly accurate positions of the wings as they move in space. Underneath the platform is a handmade and very sensitive force sensor to measure the tiny lift and drag forces from the wings, moment by moment.

The terabytes of data from this equipment will help Wood construct his next fly, one that will hover unassisted or use some rudimentary onboard control to maneuver. But right now, with dozens of new wings to flap on the little black velvet stage, Wood's next test subject is getting ready for its close-up.

Robot fly videos at makezine.com/19/robotflies

Bob Parks (xbobparksx.com) is a frequent contributor to MAKE and *Wired*. He and his son have modeled many flying machines, but so far nothing smaller than an Estes rocket.

Illustrations by Brandon Eum; photograph by J.P. Whitney

STEP BY STEP: BUG BUILDING 1.01

1. Design the wings, airframe, transmission, and actuator using SolidWorks CAD design software.

2. Prototype your design ideas in Lego or cardstock paper. Laser-cut paper for accuracy.

3. Create a 2D pattern that includes fold lines to make the parts. The airframe uses trusses to stay rigid and lightweight. The transmission has tabs where parts should fold together, so that the end result is perfectly symmetrical and accurate to 10 microns (about the size of a droplet of fog).

4. Add layers of flexible polymers to parts where joints should be. Add layers of laminate to carbon fiber to achieve the desired stiffness.

5. Autoclave in a vacuum bag to keep bubbles from forming in the laminates. Heat at required curing temperature to get everything to gel.

6. Fold flat carbon fiber patterns into 3D parts using a microscope and tweezers. Assemble the components, and epoxy together the major systems.

7. Attach the power wires and fire up the frankenfly.

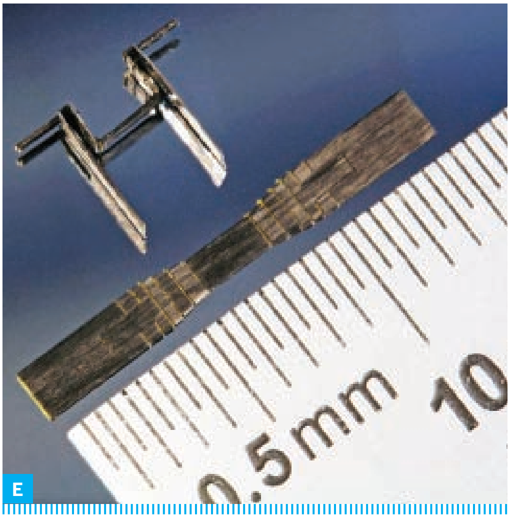


Fig. E: Folded (top) and unfolded (bottom) transmission for Harvard's micromechanical flying insect.

DIY BUGS: WHAT YOU NEED

Anyone can try creating robotic insects. Here are two approaches from academic research:

Harvard Micromechanical Flying Insect

This process requires specialized lab equipment:

Carbon fiber such as M60J from Toray Carbon Fibers America. Rob Wood buys a large roll from an aerospace company for thousands of dollars per kilogram, but thinks maybe you can find a swatch online. "You don't need much!" This type comes pre-impregnated with adhesive.
Polyimide polymer film such as Kapton from DuPont. It survives heat well, and stays flexible in the robot joints. Under $30 for a small square.
PZT piezoelectric ceramic You can buy a little for scientific use for under $100.
Curing oven The lab uses a discarded pizza oven.
Excimer laser micromachining tool Wood concedes this is probably out of reach for the do-it-yourselfer. The tool drills tiny holes and cuts lines one-tenth of the width of a hair. His lab started with an excimer laser from TeoSys Engineering (price: $50,000), but recently bumped up to the Cadillac of laser cutters from Photonics Industries (price: you don't want to know).

Berkeley Hexapod Crawler

A better DIY option from Ron Fearing's group:

2D CAD software Solidworks, CorelDraw, etc.
VersaLaser laser cutter
Posterboard
Glue stick or hot mount adhesive
Polyester film, 0.001"–0.004" thick
Glue white or cyanoacrylate

DIY instructions for a hexapod crawler robot are online at makezine.com/go/hexapod, along with downloadable design files in SolidWorks, DXF, and JPEG formats. The crawler can be powered by shape-memory alloy or by a motor. The same page has a prototype design for a "micromechanical flying insect."

The laser cutter is still spendy ($9,000–$17,000), but these machines are widely accessible in local trophy and awards shops, jewelry and gift shops, and other businesses that do engraving.

TEACHING AN OLD BOT NEW TRICKS

Make a vintage robot smarter.

BY ROBERT L. DOERR

A

Photography by Nathan Garcia

During the 1980s, as the personal computer industry was taking off, several companies introduced personal robots for home use. It was an idea ahead of its time, and while these robots didn't go mainstream, they earned a devoted following that has been having fun hacking and tinkering ever since.

The most popular "antique" personal robots are the Heathkit HERO series, RB5X, Androbot Topo, Omnibot, and Maxx Steele. Rarer models, such as the Arctec Gemini, Hubot, and SynPet Newton, are now valuable collector's items. And as time goes by, if you ask me, these old robots just keep getting cooler-looking.

There are some classic bots that I prefer to restore and preserve the way they are. But these robots also have ample room for upgrading with current technology. It isn't hard to add new features, and if you do it right, you get the best of both worlds: a cool retro robot with modern programming and control capabilities.

Adopt a Robot

To find a classic robot, check eBay, Craigslist, and robot user groups online (makezine.com/19/oldbots

for links). The robots also show up at garage sales, estate sales, flea markets, computer and electronics swap meets, and school auctions. You never know when you'll find one, but it's very exciting when your persistence pays off.

When you do find vintage robots, anything that isn't physically attached to them will typically be lost, including remotes, chargers, and documentation. Fortunately, some models are still commercially supported, even if it isn't by the original manufacturer. Rhino Robotics provides parts and support for their Rhino robot arms. RB Robotics handles the RB5X and is very helpful with parts, upgrades, and support. The HERO robot line was sold to Mobile Ed Productions back in the mid-90s, but several years ago I acquired it myself. I now carry replacement parts, documentation, and even some new options to keep these great robots alive.

Improve Its Communication Skills

Ideally, a robot should be smart enough to get around on its own. By connecting your robot to a PC, it can benefit from more information about what's going on around it, giving it greater autonomy. The host PC can run a custom application you write,

Fig. A: A sample of the author's restored personal robots from the peak of the "robot revolution" of the 1980s. The re-brained BOB is on the upper right with his front cover removed to show his new brain. Fig. B: The author in his HERO robot parts room where some of the restorations take place.

or you can use something like Microsoft Robotics Developer Studio (RDS). Either way, the computer does the heavy thinking and controls the robot like an intelligent peripheral.

To make the connection, you can leverage the RS-232 serial port that most early robots originally used just for loading their programs onboard. Serial ports have become extinct on newer computers, but there are several ways to bridge the gap and get the two talking again.

» **USB-to-Serial** For a tethered connection, my favorite method is to use a USB-to-serial adapter based on the FTDI chipset. The drivers come standard with most operating systems, and once you plug the adapter in, it appears as a standard serial (COM) port on the host PC. The adapters come in several flavors. If your robot has a standard serial port, with a DB9 connector and the appropriate RS-232 voltage levels, you can use a regular USB-serial adapter available at

C

computer stores.

Otherwise, if there is a logic level serial signal available, you can directly wire up the FTDI chip without needing an extra RS-232 voltage converter such as a MAX232. The FTDI chip is surface-mount, so it's hard to solder, but the DLP-USB232M from DLP Design lets you put it right on a breadboard or place it in a DIP socket.

I made a USB interface for the HERO 1 using the FTDI FT232RL chip. The interface plugs into the breadboard area on the robot's head just like the original serial port did. Using the MProg utility, available at ftdichip.com, you can customize the behavior of FTDI chips to fit your application. As long as you don't change the Vendor ID or Product ID fields, the chip's default drivers will continue to work, but you can change the Product Description field so that a Windows machine will say it found a "HERO 1 Robot" when you plug in the USB cable!

» **Bluetooth** Another option is to cut the cord and run a wireless connection. For Bluetooth, I would recommend going right to the Class 1 devices so you can get the extended range (up to 100 meters). A couple of modules on the market convert Bluetooth to a standard RS-232 port, and in many cases, can plug right in. One that works well with the HERO 1 is Grid Connect's Firefly GC-BT-BLUEPORT module with DTE connector.

I've modified a HERO 1 Serial Interface to use a DB9 connector and supply power for one of these, and the whole thing plugs neatly into the breadboard area on the robot's head. I also like A7 Engineering's eb-501 Bluetooth modules, which already have an onboard RS-232 interface, as well as 3V and 5V logic level signals.

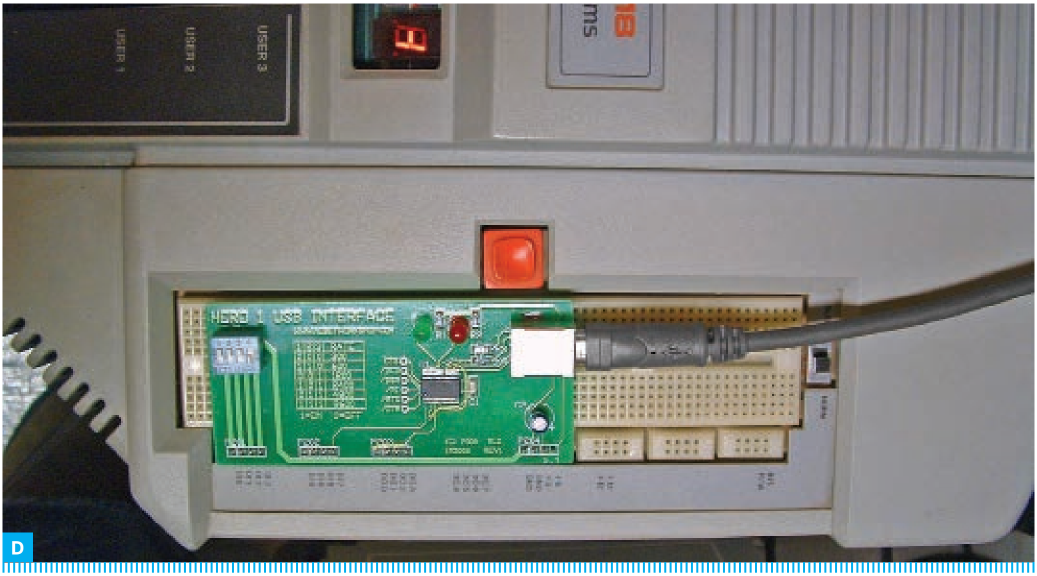
» **Wi-fi** You can also use an existing wi-fi LAN to remotely control the robot. The WiPort and WiMicro modules from Lantronix, and the WIZ610wi-EVB board from WizNet can all bridge a wireless LAN to either 1 or 2 serial ports, for connecting to a robot.

Give It a Better Memory

Even with computer control, you may still want to augment the robot's capacity to operate on its own. With older bots, especially the rarer ones, I prefer enhancements that plug in and bolt on, so the robot's design isn't altered and you can restore its original configuration, if desired.

The original HERO 2000 robot memory had 24K standard, and you could install an additional 576K by populating its three ET-19-15 static memory boards with a whopping 72 memory chips. Several

Photography by Robert L. Doerr



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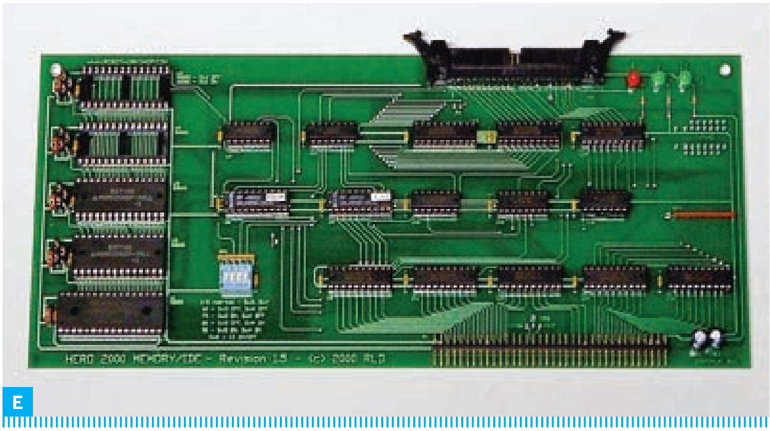

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Fig. C: The author's parts room, which includes redesigned and remanufactured circuit boards that use newer technology.
Fig. D: The author's HERO 1 USB interface installed on the robot.
Fig. E: HERO 2000 H2KIDE board Memory/ IDE interface.

years ago I designed an "H2KIDE" board for the robot, which matches its original maximum amount of memory using just three RAM chips, and lets you add more. It also adds an IDE interface that lets you connect a 2.5" laptop hard drive for program and data storage. It's the equivalent of adding a 16-bit IDE drive to an older 8-bit PC, which would have only had MFM or RLL drives back then.

With an adapter, you can also use a Compact-Flash card, since it mimics an IDE drive. This option allows the robot to easily recall programs saved on the hard drive and also store plenty of data about its travels, which can be transmitted up to a higher-level intelligence on a host PC. This is where a Bluetooth or wi-fi connection really helps.

Transplant Its Brain

While I prefer to do original restorations on robots, it isn't always practical or possible. For example, I once ended up with an early Androbot BOB prototype, but its original brains were gone and irretrievable — I'd heard they were recycled to build other robots before the company folded. This BOB had been neglected for years, and he sat for a few more while I unsuccessfully tried to find technical details on his electronics. It was surprisingly depressing, seeing him as an empty shell, so I decided to bring him to life using a new brain, but in a way that I could undo just in case the original brains were ever found. I wouldn't even drill any holes.

For the new brain, I used an MIT Handy Board (handyboard.com) with the optional expansion board. The Handy Board is a 68HC11-based controller designed for experimental mobile robotics, and although there are lots of newer microcontrollers on the market, it's still great for many projects. Its

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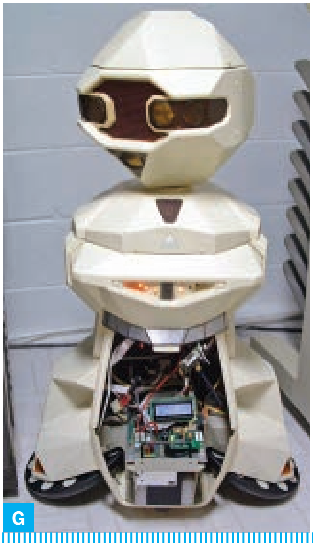

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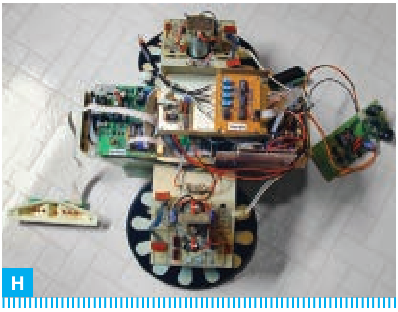

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Fig. F: Gutted BOB as originally found (with no electronics). Fig. G: Working re-brained BOB. Fig. H: New electronics on BOB base. Fig. I: The virtually brain-free Topo I in the author's workshop. Fig. J: Two Androbot Topos, the regular production model (right) and a rare blue prototype (left).

I

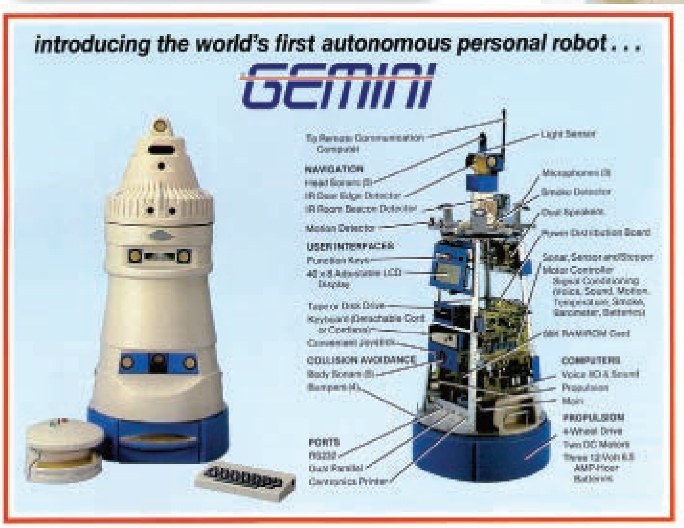
J

Interactive C environment already provided a lot of the functionality I wanted, and it's easy to add custom functions using the library of add-on code and examples on the Handy Board users group.

Anytime you "re-brain" a bot, you lose the functionality of the original program and supporting routines. The Handy Board supports many of the low-level features I needed to re-create BOB's original functionality (sonar, drive motors, sensors), but I needed to build the rest.

Since I wanted BOB to act like the original prototype, I was able to get a few clues on how he acted from a couple of people who used to work for Androbot, and also from a few fragments of Forth code that turned up for the BOB/XA (one of BOB's Androbot siblings, characterized by a bow tie). It was a rewarding process, and although there were plenty of challenges along the way, it turned out better than I could have hoped. I documented the project in a series of 4 articles in *Servo* magazine, February through May 2008. Using the same basic principles, I could have used almost any other microcontroller. One newer one I'd consider is the Parallax Propeller, which has a lot of potential.

Some other robots are basically just remote control toys that are begging to get a brain installed. The original Androbot Topo I, for example, has motor drive electronics that accept the standard R/C signals that most microcontrollers (including BASIC Stamp and Arduino) can generate. Other robots, like



THREE ORIGINAL ADS FOR RARELY SEEN ROBOTS OF THE MID-80s: The Hubot was touted as the ultimate appliance, with an onboard computer, TV, Atari 2600 game system, and stereo. The Gemini was one of the most capable robots of the era, with an excellent navigation system. BOB held a special position as the Cadillac of the personal robots, but unfortunately never made it out of the lab.

the Tomy Omnibots, were made in decent numbers and are less precious. One of these would make a great starter robot if you wanted to add a microcontroller brain. With either of these bots, you're not losing any original programming by installing new brains. Anything you write is going to be more than what was there to begin with.

Put It Online

Once you get your robots going and upgraded so they can talk over your home network, what comes next? Why not give them some additional smarts by letting them use the internet! You could do this directly with a PC controller onboard your bot, or else by running an "infomediary" application on the PC — middleware that gathers information for the bot, strips out anything extraneous, and transmits it in some format the bot can understand. The program could be as simple as a set of scripts that pull Google data whenever you ask the robot what's going on in the world. Or it could pull down weather forecasts or Wikipedia entries. Using this strategy, the robot can act smart, even if the AI hasn't caught up yet.

+ For vintage robot user groups, serial-to-wireless module sources, and other online resources, see makezine.com/19/oldbots.

Robert Doerr runs robotswanted.com, robotworkshop.com, and robotgallery.com. He also writes for *Servo* magazine.

THE ACCIDENTAL PIONEER

How a neurophysiologist's experiments in brain behavior created the first autonomous robots.

BY GARETH BRANWYN

Photography by Larry Burrows / Time & Life Pictures / Getty Images

The photo shows a hipster with a goatee smoking a cigarette, watching his pet robots navigate his mod living room. An earlier video shows the man and his wife laughing and playing with their two bots, Elmer and Elsie, as the two machines interact with each other, navigating the room and obstacles, one of them driving into its little recharging "hutch" on the floor.

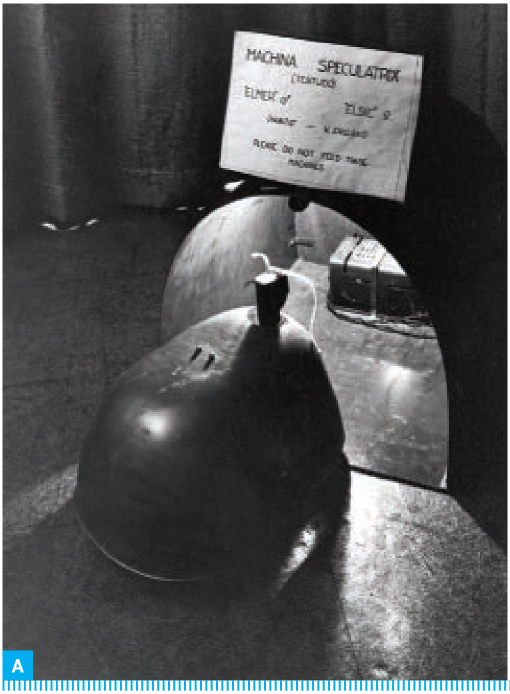


Fig. A: Elsie seeking the bright light of her charging station, April 1950. Sign reads "Machina Speculatrix (Testudo)/ Elmer Elsie/ (Habitat — W. England)/ Please Do Not Feed These Machines." Fig. B: Time-lapse photo of Elsie allegedly performing in front of a mirror, enamored with her pilot light — or is she actually responding to the candlelight used in the time-lapse?

What year do you think this is? 2009? 2001? Sometime in the 1990s? Certainly no earlier than the 1980s?

Try 1949.

The location is Bristol, England. The man is Dr. W. Grey Walter, a neurophysiologist. His wife, Vivian, is also a scientist (and helped him build the robots). They both work at the Burden Neurological Institute (BNI).

As part of his research into brain cell behavior, Walter has created these simple, autonomous robots from analog electronics. And while the influence of these experiments on brain research is debatable, Walter's robot experiments would lay the groundwork for one of the more successful fields of robotics today (though that ground would remain fallow for decades).

Pioneer of the EEG

William Grey Walter was born in Kansas City, Mo., in 1910. He was brought up in England, where he attended Westminster School and then King's College, Cambridge. In 1939 he got a job at the BNI. Although he's best known for his robot experiments in the 40s and 50s, his most significant work was in the burgeoning field of electroencephalography (EEG).

It was in the course of his work with EEG, and his growing interest in the postwar science of cybernetics, that Walter became interested in experiments that could explore the control mechanisms of the brain. He became intrigued with the idea of creating a mechanical, goal-seeking animal that could scan an environment. He thought he could use these creatures to model simple neurons in the brain and to study how these neurons interact.

Walter wondered if, instead of it being the sheer numbers of neurons that led to complex brain functions, it was the richness of how these neurons interconnected that led to this emergent complexity. If he created the simplest machines, with two-neuron-brains (two vacuum tubes), endowed with a few senses (sight and touch), would he witness some unforeseen complexity in behavior emerge? Especially if he had multiple machines interacting?

Speculating Machines

Walter began work on his first robot sometime in 1948. The prototype was dubbed Elmer, followed by a more reliable, fuller-featured version, Elsie (the two names are derived from *ELectroMEchanical Robots, Light Sensitive with Internal and External*

Walter was very much a showman who enjoyed the attention he got for his robots.

stability). The robots were called "tortoises" because of the shell-like, bump-sensitive bodies that covered them. He also called them *Machina speculatrix*, Latin for "machine that speculates."

Built with postwar military surplus, each electromechanical tortoise was three-wheeled, with a front drive wheel and two unpowered rear wheels. Each side of the bot carried a vacuum tube "neuron" and a relay. Power to the robot was provided by a 3-cell lead-acid accumulator.

An ingeniously designed touch-switch at the top of a mast toward the back made the entire shell touch-sensitive. Any pressure against the shell would close the circuit and trigger an avoidance sequence. The main active sensor was a photoelectric cell housed on a rotating spindle at the front of the robot, above (and connected to) the drive wheel. Once a light source was detected, a linear gear would disengage and the drive wheel would be fixed in the direction of the light.

By using the switching power of two relays, and the amplifying (and oscillating) power of the two vacuum tubes, a series of "behaviors" could be orchestrated within the circuit:

Pattern E: Exploration. Moving around in a room without a light source to follow

Pattern P: Positive phototropism. Moving toward a light source

Pattern N: Negative phototropism. Moving away from a strong light source

Pattern O: Obstacle avoidance. Pushing, turning, and recoiling to push away and/or steer clear of obstacles

Another important aspect of the design was what Walter called "internal stability." Today we might call it autonomy — the ability of the bots to "feed" themselves. A hutch was built with a charging mechanism inside. As the tortoise's battery died, the gain on its tube amps would be decreased, making it harder to engage behavior N (normally, the brightness of the light would trigger pattern N) and the bot would be attracted to and drive toward an ultra-bright light in the back of the hutch. Once the battery was fully charged, pattern N would be excited again, and the tortoise would react to the light by backing out of the hutch.

From 1948 into the early 50s, Walter did studies with Elmer and Elsie. Six other tortoises were built by BNI technician W.J. "Bunny" Warren. In 1950, Walter published his findings in an article in *Scientific American* entitled "An imitation of life." This was followed by a second article in *Scientific American*, entitled "A machine that learns," in 1951, and by a book, *The Living Brain*, in 1953.

In these publications, Walter reported that he'd witnessed surprising behaviors in his interacting tortoises. He claimed to have seen actions he was unafraid to call "goal-seeking" (starting out in the dark and making way toward a light source), "recognition of self" (bots "performing" in front of a mirror), "discernment" (making distinctions between effective and ineffective behavior), and "free will" (exhibiting unpredictable behavior and making choices). He witnessed what we'd call "emergent behavior" today. He saw things in the robots that he didn't design into them, and saw unanticipated behaviors emerge from interactions between bots.

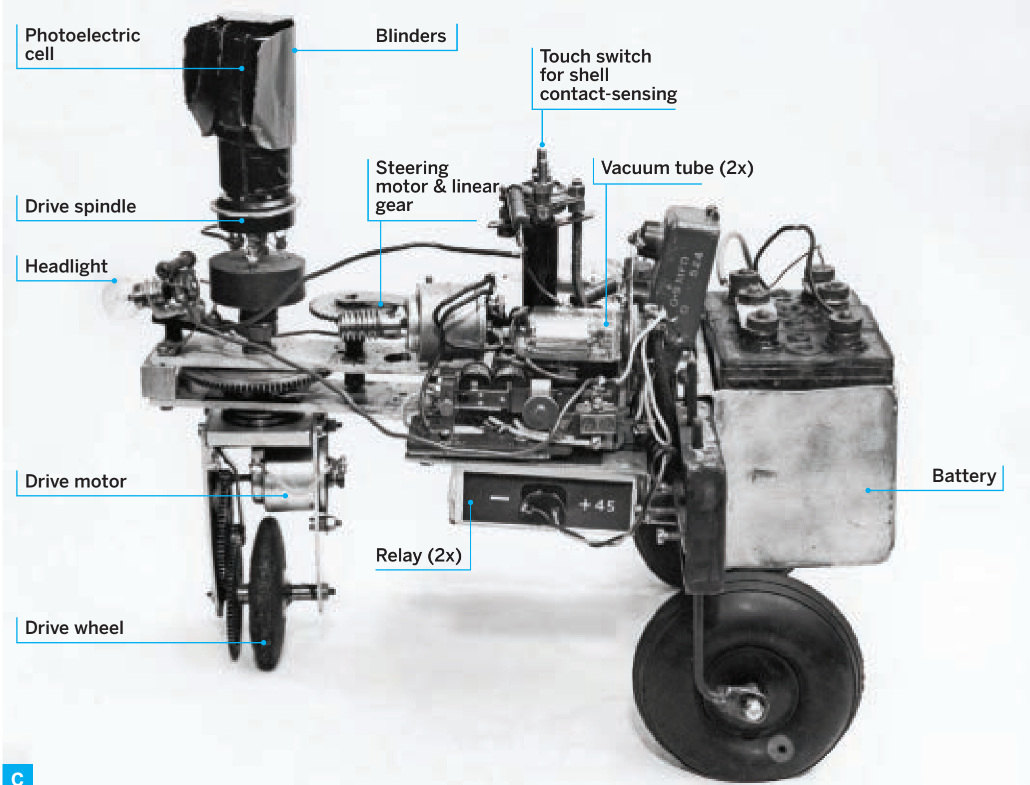
Ever the Showman

Most of the articles about Walter's experiments, and the information available online (much of it inaccurate), take him at his word and don't question his findings or the effectiveness of his designs.

Professor Owen Holland, from the computer sciences department of the University of Essex, built two replicas of the tortoises (with Bunny Warren) and has carefully studied Walter's findings, photos of the tortoise experiments, and such artifacts as the BBC newsreel footage mentioned in this article's opening paragraph (see at makezine.com/19/greywalter).

Holland points out many inconsistencies in the conclusions and the surviving evidence of the experiments (such as the famous time-exposure photographs of Elmer and Elsie taken in late 1949 or 1950), and obvious fudges and edits to the BBC newsreel to, for instance, imply that Elsie has made her own way into the charging hutch. There's no evidence (or even written claim) that the charging hutch ever actually worked.

But even with some questionable conclusions, the documented accomplishments of these experiments are impressive, and their basic observations are borne out by today's simple "behavior-based robots" (BBR), such as BEAM robots (see *MAKE,*



Volume 06). As Holland pointed out in a 2003 paper for the Royal Society, Walter was very much a show-man who enjoyed the attention he got for his robots. He was more than happy to appear in newspaper articles, on radio, and in newsreels, showing off his robots and what one colleague called his "immense talent for persuasive oratory" — which, Holland adds, "may have occasionally carried him beyond the facts."

The Legacy of Grey Walter

In following the trajectory of robotic development, you'd think a major course could be confidently plotted through Grey Walter and his pioneering work, but you'd be wrong. Thanks to the popular fix-ation on highly intelligent humanoid robots, we lost sight of the less sexy bottom-up, utilitarian robots. It wasn't until researchers like Rodney Brooks at MIT started experimenting with behavior-based robotics in the 1980s, and Mark Tilden developed BEAM soon after, that people started to take another look at Grey Walter's pioneering work.

Look at a teardown of the first Roomba, and you'll be shocked by how few parts were inside. It was basically an electric broom, some bump-sensors, and a recharging circuit (not that different from Elsie). It's amazing to think that if others had picked up on Walter's work in the 1950s and seen it as a legitimate path to robotic development, we easily could have had something like Roomba in that decade. Imagine where robotics might be today.

It's also significant that two of the most successful commercial robot companies today (and there aren't many), iRobot and WowWee, are both built on BBR, an approach that Grey Walter would enthusiastically recognize as the direct descendant of his own.

Fig. C: The anatomy of Elsie. Sadly, she (and Elmer) did not survive. Of the six second-generation tortoises, two survive, one in the Smithsonian, the other in the Science Museum in London.

Special thanks to Professor Owen Holland for providing us with two of his papers, "Exploration and high adven-ture: the legacy of Grey Walter" and "Grey Walter: the pioneer of real artificial life." Much of the information in this article comes from these papers (though any errors are ours alone).

See the tortoises in action at makezine.com/19/greywalter

Gareth Branwyn is a senior editor at MAKE.

RUNAWAY ROBOTS

Rovers at the first annual SparkFun Autonomous Vehicle Competition have minds of their own.

BY MARK FRAUENFELDER


A

B

2 p.m., April 15, 2009, in an industrial parking lot outside Boulder, Colo.: It's not looking good for Team DIY Drones. Their entry, a self-guided airplane, is now stuck in a tree 150 feet above the racecourse.

Five minutes earlier, team member Jordi Muñoz, an experienced remote control pilot, made an error while preparing the drone for its third autonomous run around the course, and it plowed into the branches. The drone's first and second runs had been disqualified for clipping the corners of the competition course. Now Muñoz and his fellow team member, *Wired* editor-in-chief Chris Anderson, are staring up at their drone like a pair of Charlie Browns foiled by the kite-eating tree.

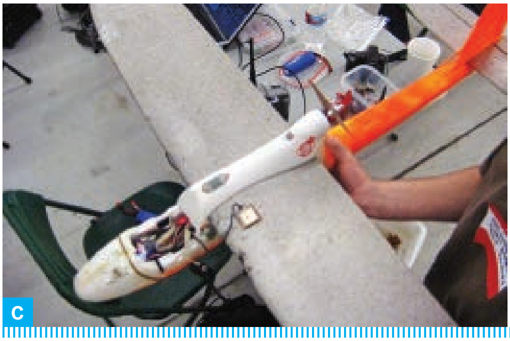
2:10 p.m.: Someone from the crowd is shimmying up the tree to retrieve the drone, but a man who looks like a drill sergeant stomps out of a nearby building and shouts, "Get down from there! We don't have insurance for anyone to climb trees!"

Earlier that day, 9:50 a.m.: Sixteen teams are hunched over tables in SparkFun's warehouse, making last-minute adjustments on a menagerie of wheeled, winged, and spherical vehicles. They're participants in SparkFun's first Autonomous Vehicle Competition, and they've traveled from as far as Oklahoma and California to find out if their robot can circumnavigate the parking lot around Spark-Fun's headquarters in the shortest time.

It seems like a simple challenge — only four left turns are required to complete the course — but because the vehicles must navigate under their own control, using onboard positioning technology and collision avoidance (base stations are forbidden), it's a much harder task than one might think.

Team DIY Drones is brimming with confidence at the prospect of winning. As the only entrants with an airborne vehicle (a styrofoam, remote-control model airplane outfitted with a guidance system they designed called the ArduPilot), Anderson and Muñoz have both speed and an obstacle-free path

Photography by John Maushammer (above left) and Mark Frauenfelder



C

D

on their side. The other competitors grouse about the fairness of having to race wheeled vehicles against an airplane.

Fig. A: Jordi Muñoz with drone. Fig. B: Tree eats drone. Fig. C: Drone escapes tree. Fig. D: SWOSUME — an autonomous ice chest on wheels.

10 a.m.: A crowd of 50 people gathers around the starting line. In the first heat, four vehicles lead off in the right direction, but are unable to make a left turn and can't reach the second waypoint.

Just when some people begin to wonder whether the challenge is ahead of the current technology for hobby autonomous vehicles, Team MookeMobile's Deathpod3000 gives the crowd hope. The modified remote control race car handily makes the first turn, and the competitors and spectators, who are allowed to roam freely on the course, run behind it, cheering and laughing. Deathpod3000 makes the second, third, and fourth turns, returning to the starting point. The other teams are delighted to witness the milestone, not only out of camaraderie, but because they now know it's possible.

10:45 a.m.: It's Dennis Ferron's turn. The good-natured 25-year-old, who is studying for his doctorate in software engineering, sets SWOSUME on the starting line. The other cars in the race measure 2 feet or less, but SWOSUME is built from an ice chest, and its motor and wheels come from a Power Wheels car — the kind a kid can sit in and drive around the backyard.

The judge gives the signal and Ferron flips a switch. SWOSUME rumbles across the rough asphalt, its hard plastic wheels spitting up gravel.But instead of turning left it drives straight off the lot and enters a field of tall weeds and gets stuck.

Ferron trots after SWOSUME into the field, sits on it, and uses the remote control to steer it back onto the lot. His weight puts a strain on the rover's power controller and it starts smoking. "No problem," says Ferron. If one of the motor control channels burns out, he explains, he'll just run the motor from one of the unused channels.

11 a.m.: The employees of SparkFun have their own team. Their vehicle, OhCrapTheresALake (referring to the pond beyond the parking lot), shoots off the starting block, bounces on all four wheels, and makes wild, unpredictable turns. It starts chasing people. Two spectators have to jump over the crazed machine so it doesn't ram their feet. The crowd scatters in a giddy half-panic, until the beast collides with the curb, which discombobulates it long enough for its handlers to hit the kill switch.

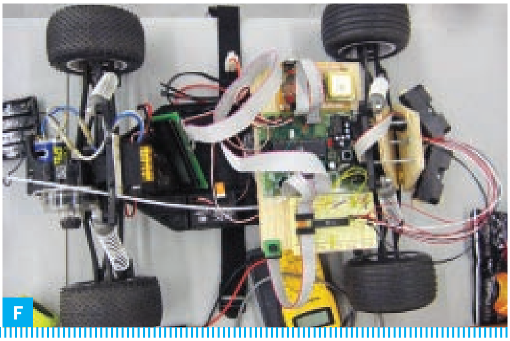
Why are the rovers having trouble? For one thing, says Nathan Seidle, CEO of SparkFun, skewing problems with GPS can make a vehicle think it's 20 feet from where it really is. Anderson says that Google Maps, which he and Muñoz use to mark waypoints for their drone to fly to, has accuracy problems that they compensate for by tweaking the flight plan. They were disqualified in the first heat for clipping the corners of the course, but Anderson is not discouraged. "We'll nail it," he says.

Besides location and mapping problems, many of the vehicles have internal bugs. A professional hacky sack maker from Gunnison, Colo., explains that his car, 401K, failed because the "latitude conked out in the software. I probably messed up a line of code."

Team BOB ("bouncing off bumpers") is trying to trace the short circuit that fried the MOSFETs in their vehicle's control system. LabRats' Spheroid, which runs like a hamster in a ball, is comatose for unknown reasons. And Old Man Earl drove ten hours from New Mexico with a non-working quadrocopter just to show it to folks, promising it will be ready to compete next year.

Every vehicle has had one shot so far (they'll get three chances), and Deathpod3000 is the only one that has completed the course successfully. Built by Denver software developer Eric Moore and his

E



F

Fig. E: OhCrapTheresALake is retrofitted with an orange cone to warn spectators of its approach. Fig. F: A pit stop for Deathpod3000.

teenage son, Deathpod3000 represents design based on observation. Weeks before race day, Moore visited the course and came to the conclusion that the curbs would be a deadly hazard unless he outfitted his vehicle with proper collision avoidance technology. Other teams mainly use sonar to detect obstacles, but sonar projects a broad cone of sound that's too inaccurate to detect curbs. Instead, Deathpod3000 uses infrared ranging sensors, which locate obstacles with a pencil-thin beam.

12:21 p.m.: Deathpod3000's first run had its throttle set at 30%. Its second run, at 50% throttle, completes the course in 1:28, shattering the 2:07 record it had set just hours ago.

1 p.m.: It's OhCrapTheresALake's turn again. This time, the crowd keeps a respectful distance. Its owners have taped an orange traffic cone to its body, as fair warning for anyone who wants to stay on the parking lot during its run.

At the signal, it pops a screaming wheelie and makes a beeline in the opposite direction from the course. It hops the curb, flips in the air, and splashes into the creek. Someone wades in after it. The vehicle is eerily silent. It's finally, blessedly dead.

2:20 p.m.: Deathpod3000's final run, at 70% throttle, tears off the starting line. But the microprocessor that interprets the IR sensor data can't compute quickly enough, and the vehicle, like so many of its brethren this day, ends its run by bashing into the curb. No matter — since Moore fielded the only vehicle to finish the course so far, it seems almost certain that he'll be going home with the $300 grand prize. Only one other vehicle has even made it around three turns, let alone four. Everyone agrees the trophy is as good as Moore's, especially with Muñoz and Anderson's drone (which was disqualified in the second round for clipping corners again) stuck in a tree.

2:25 p.m.: But then three Boulder County firefighters arrive in a fire engine with a ladder. In a few minutes they've retrieved the autonomous plane. The Droners have one final chance to show their stuff. But it's now past 2 o'clock, and the wind has kicked up, which is bad news for the lightweight plane.

Anderson and Muñoz decide to increase the radius of the flight path to avoid corner clipping. Muñoz twiddles with a laptop, clicking new waypoints on a Google map. He launches the drone and aims it toward the starting line. As soon as it's on course, he holds the remote control over his head, to make it clear that the drone is in autonomous mode.

Gusts rock the foam plane back and forth as it approaches the starting line. Judges stationed at each of the four corners of the building look up to make sure the drone doesn't drift across the border between the outer walls and the parking lot. The drone describes a large circle around the perimeter of the building. All four judges give word that the drone has cleared the corners. Final time: 0:36.

The other team members congratulate the winners, and then, just for fun, everyone sets their rovers on the ground and starts them at the same time. Robot mayhem ensues, but oddly enough, none of them collide.

THE WINNERS

1st Place: DIY Drones II, makezine.com/go/avcdiydrones

Engineer's Choice: Deathpod3000, makezine.com/go/avcdeathpod

For more competition images and video: makezine.com/19/avc

Mark Frauenfelder is editor-in-chief of MAKE.

Make: Projects

Hands-on work can strengthen your brain as well as your muscles, and we've got a variety of projects to stretch your skills. Create your own devoted friend in the form of a robot who follows you around, build a super-comfy kick-back chair out of plywood, and tell people how fast you're pedaling with an illuminated safety vest.

Makey The Robot

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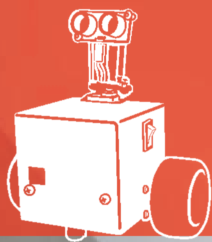


Plywood Rok-Bak Chair

88

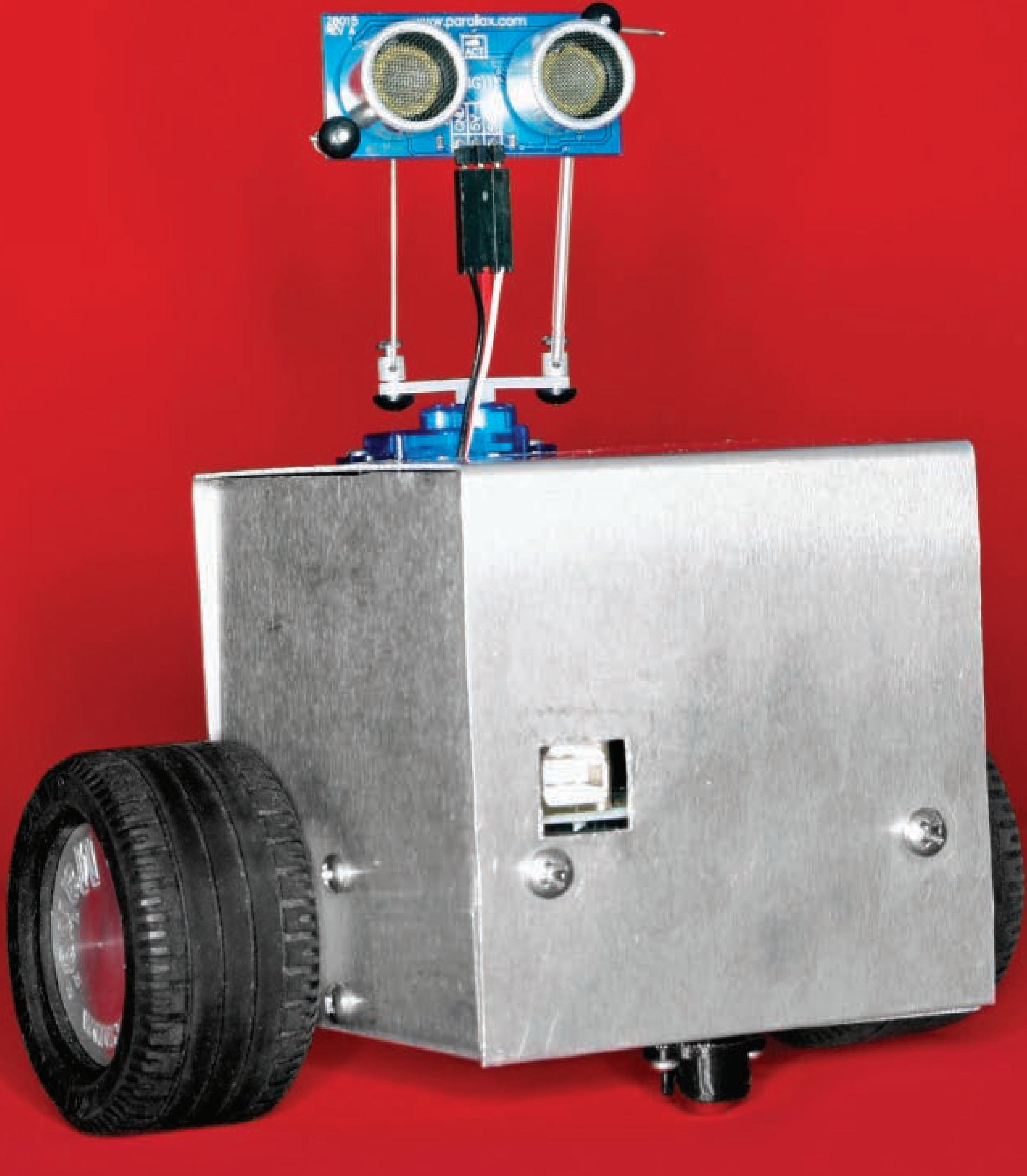
Light-Up Speed Vest

100

Photograph by Sam Murphy

MY ROBOT, MAKEY

By Kris Magri



ROBOT ON, DUDE

I've made some fun robots, but I never liked the way they look, with their parts stacked up, and black tape and visible wires running everywhere. I decided to build a bot that combined tried-and-true workings with some Hollywood bling. I sketched some ideas, and this is the one that spoke to me.

Makey is an autonomous robot that I've programmed to follow objects around. It uses tank steering, aka differential drive, where separate DC motors power each of the 2 drive wheels. A servomotor moves its head, which carries a single ultrasonic rangefinder. Control comes from an Arduino microcontroller, which I've programmed to do object following and obstacle avoidance. With these behaviors, Makey constantly turns its head right and left to acquire differential ranging data, adding to its personality.

The chassis design is unusual in that there are no exposed components; I vowed to keep everything enclosed, which made the design harder, but it was worth it.

With different Arduino programming, the hardware would support mapping and other activities, and with a few hardware mods, Makey could also compete in Mini-Sumo, one of the most popular events in robotics competitions.

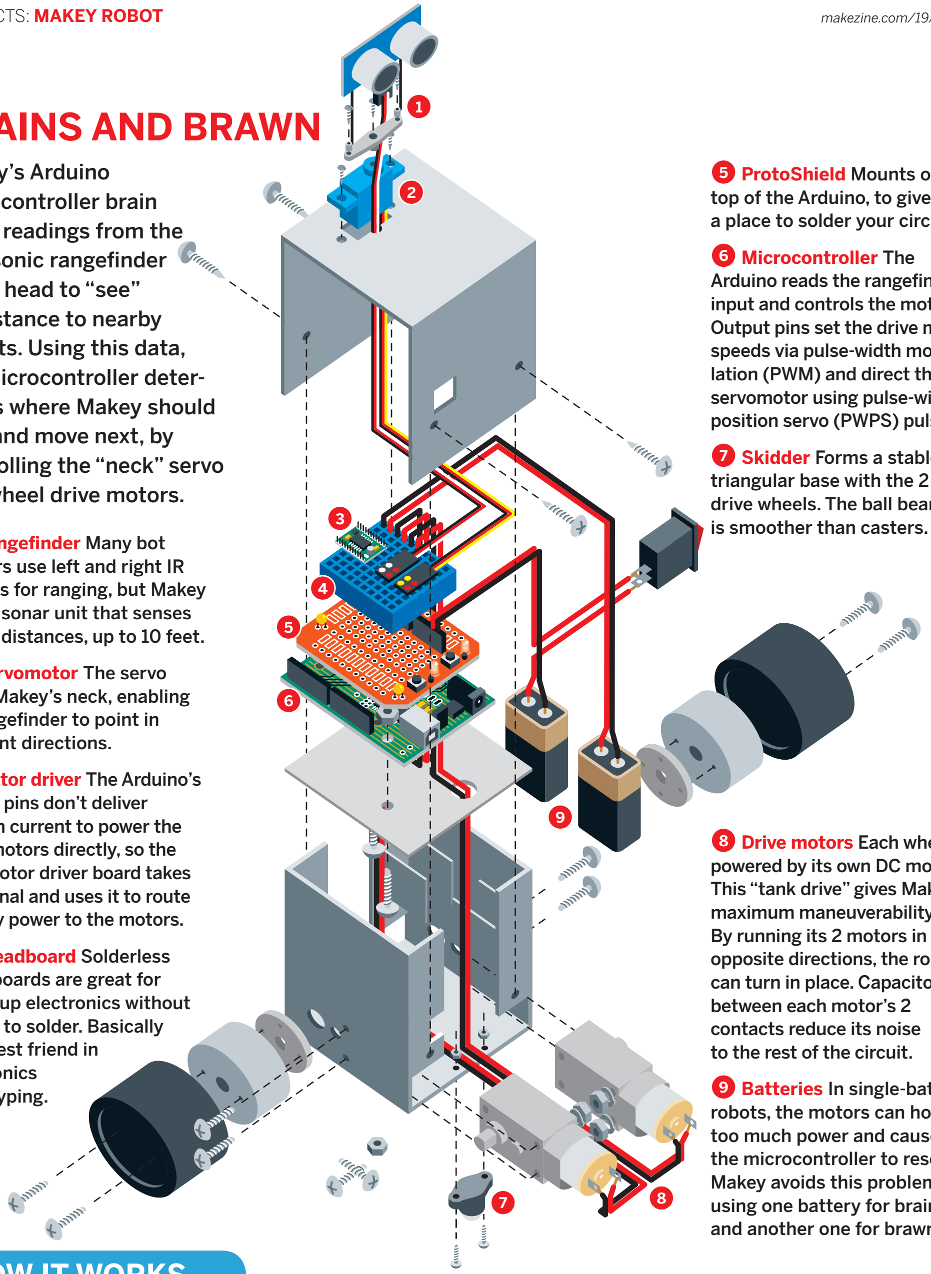
Photograph by Sam Murphy

Set up: p.79   **Make it: p.80**   **Use it: p.87**

Kris Magri is an engineering intern at MAKE who enjoys building autonomous mobile robots in her spare time.

BRAINS AND BRAWN

Makey's Arduino microcontroller brain takes readings from the ultrasonic rangefinder on its head to "see" its distance to nearby objects. Using this data, the microcontroller determines where Makey should look and move next, by controlling the "neck" servo and wheel drive motors.



1 Rangefinder Many bot builders use left and right IR sensors for ranging, but Makey uses a sonar unit that senses longer distances, up to 10 feet.

2 Servomotor The servo turns Makey's neck, enabling its rangefinder to point in different directions.

3 Motor driver The Arduino's output pins don't deliver enough current to power the drive motors directly, so the dual motor driver board takes the signal and uses it to route battery power to the motors.

4 Breadboard Solderless breadboards are great for wiring up electronics without having to solder. Basically your best friend in electronics prototyping.

5 ProtoShield Mounts on top of the Arduino, to give you a place to solder your circuitry.

6 Microcontroller The Arduino reads the rangefinder input and controls the motors. Output pins set the drive motor speeds via pulse-width modulation (PWM) and direct the servomotor using pulse-width position servo (PWPS) pulses.

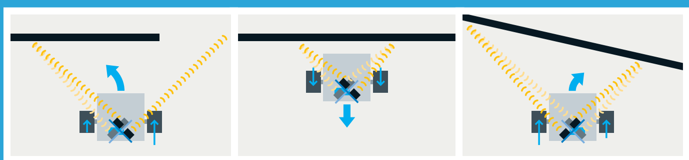
7 Skidder Forms a stable triangular base with the 2 drive wheels. The ball bearing is smoother than casters.

8 Drive motors Each wheel is powered by its own DC motor. This "tank drive" gives Makey maximum maneuverability. By running its 2 motors in opposite directions, the robot can turn in place. Capacitors between each motor's 2 contacts reduce its noise to the rest of the circuit.

9 Batteries In single-battery robots, the motors can hog too much power and cause the microcontroller to reset. Makey avoids this problem by using one battery for brains, and another one for brawn.

HOW IT WORKS

For object-following behavior, Makey's code uses a strategy called "proportional control." Rangefinder readings are compared to an optimal distance. If they are equal, the drive motors stay still. Readings are taken in pairs, facing right and facing left, with each determining the speed on that side. If nothing is within sensor range, the motor runs at maximum speed.



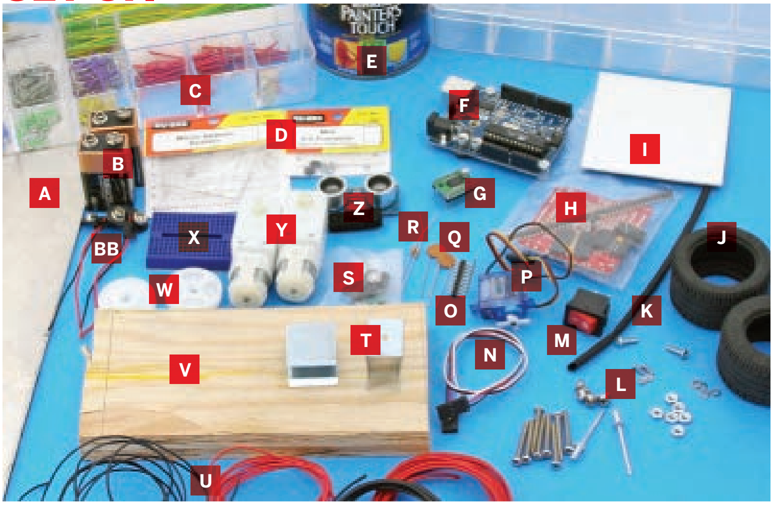
An object at far left makes the left motor run at proportional speed while the right runs at maximum. This turns Makey left.

An object at dead center and closer than the optimal distance makes the motors run backward equally.

An object slightly to the right makes the left motor run slightly faster, turning Makey to the right.

Illustration by Nik Schulz/L-dopa.com

SET UP.



MATERIALS

[A] Aluminum sheet, 0.032" thick, at least 9"×10", 5052 alloy

[B] 9V batteries (2)
[BB] 9V battery snaps (2) Jameco #11280 (jameco.com) or RadioShack #270-324

[C] Jumper wires, solid core, 22 gauge Maker Shed #MKEL1 (makershed.com) or Jameco #19290, or cut your own from solid core wire

[D] Du-Bro Mini E/Z Connectors and Micro Aileron System Hobby-Town USA #DUB845 and #DUB850 (hobbytown.com)

[E] Paint I used Rust-Oleum Painter's Touch Apple Red Gloss #1966.

[F] Arduino Duemilanove microcontroller Maker Shed #MKSP4. The Diecimila version will also work.

[G] Dual motor driver board, 1A Dual TB6612FNG SparkFun #ROB-08905 (sparkfun.com)

[H] ProtoShield kit SparkFun #DEV-07914 or Maker Shed #MKAD6

[I] Rigid plastic, around 3½"×3½"×1/16"

[J] Lego tires, 49.6×28 VR (2)

[K] Heat-shrink tubing

[L] FASTENERS
- **Machine screws: 1-72×¼" (2), 4-40×⅜" (2), 4-40×1" (8)**
- **Sheet metal screws, #6×¼" (4)**
- **Nuts: 1-72 (2), 4-40 (6)**
- **#4 lock washers (4)**
- **⅛" pop rivets (2)**

[M] On/off switch, SPST rocker Jameco #316022

[N] Servo extension wire, 12" HobbyTown USA #EXRA115, to plug into the rangefinder, not the servo

[O] 3-pin right-angle male headers (2) Break apart a 10-pin header like Jameco #2076949.

[P] Servomotor, Hitec HS-55 sub-micro HobbyTown USA #HRC31055S or ServoCity #31055S (servocity.com)

[Q] 0.1µF capacitors (2) RadioShack #272-135 or Jameco #15229

[R] 10kΩ resistors (2) RadioShack #271-1335 or Jameco #691104

[S] ⅜" metal ball caster SparkFun #ROB-08909

[T] 9V battery holder clips (2) Jameco #105794 or RadioShack #270-326

[U] Wire, solid core insulated and stranded insulated, 22 gauge, red and black

[V] Scrap wood, 1×3 or wider (¾" thick), 6" long

[W] GM2/3/8/9/17 gearmotor mounts (2) aka hubs, Solarbotics #GMW (solarbotics.com)

[X] Mini breadboard for ProtoShield, SparkFun #PRT-08801 or Maker Shed #MKKN1

[Y] Drive motors, Gearmotor 9 (2) Maker Shed #SBGM9 or Solarbotics #GM9

[Z] Ping rangefinder RadioShack part #276-031 or Maker Shed #MKPX5

TOOLS

9" bandsaw with ⅛" metal cutting blade

18" bending brake Harbor Freight (harborfreight.com) #39103-8VGA, $35

Drill press with vise clamp and scrap wood block

Fractional drill bit set

#43 drill bit

Step drill, aka unibit, Harbor Freight #91616-0VGA

2" hole saw

4-40 tap and tap handle

Pop rivet tool

Small metal file

Drafting square

Center punch and small hammer

Nibbler tool Jameco #18810, $8

Handheld deburring tool

Soldering iron and solder

Screwdrivers for screws and servo parts

Needlenose pliers

Double-sided and regular cellophane tape

Double-sided foam tape

Black electrical tape

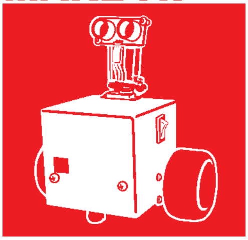
Small nail

Protective eyewear

Computer with internet connection and printer

Photography by Ed Troxell

MAKE IT.



BUILD YOUR MAKEY ROBOT

START **Time:** 2-3 Weekends **Complexity:** Difficult

1. MAKE THE BODY

The body consists of 2 pieces of sheet aluminum. You can cut, drill, and bend one piece at a time, or do both at once to minimize switching tool stations; see Step 1h.

1a. Download the 5 Makey templates from makezine.com/19/makey and print them out full-size. Cut out the base cutting template, and cut holes in the blank area of each panel. Securely tape the template to the aluminum sheet with double-stick tape on the back and regular tape over the holes.

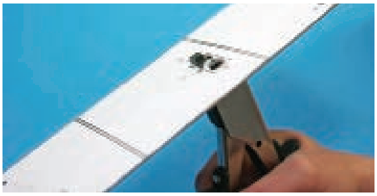
1b. With a band saw, cut the aluminum roughly to size around the template, then cut the perimeter just outside the lines.

TIP: For inside corners, first cut a gradual curve close to the corner, then back up and cut into the corner's point from each direction.

1c. Use a center punch and small hammer to punch through the template at the 17 crosshairs (for drilling in the next step) and at the corners of the rectangles around the large holes.

1d. Drill the holes at the crosshairs following the sizes marked on the template. Remove (but keep) the paper first, to line up on the punch marks more accurately. Clamp the metal tightly onto scrap wood, and wherever possible use the unibit, which makes cleaner holes in thin metal than a twist drill. For the starter holes inside the rectangles, you may need to adjust the diameter smaller or larger to reach the rectangle edges.

1e. Finish the rectangular holes with the nibbler tool, cutting away until a rectangle appears. If you want, you can retape the template to see the rectangles more clearly. Then file the edges smooth.



1f. Use a handheld deburring tool to remove burrs from the metal's edges. To deburr the small holes, push the point of a larger drill bit over the holes and twist it by hand.

1g. Cut out the base bending template and attach it to the other side of the aluminum with double-stick tape, aligning the holes and rectangles. Insert the metal in the brake with the new template facing up, and make all indicated bends at 90°. For each bend, go up gradually, using a drafting square between small bends to check the angle. First bend the tabs on each long side of the metal, then bend up the sides of the body.

1h. For the body's top cover, repeat Steps 1a–1g using the top cutting and bending templates. Now you've got one sweet chassis any robot would be proud to wear!

2. ADD THE DRIVETRAIN

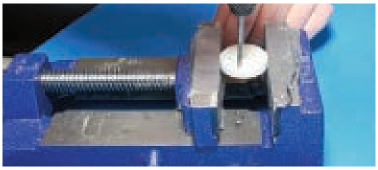
2a. Mount the drive motors in the base using 4-40×1" screws through the small holes. The motor shafts should poke out of the larger holes. Secure the screws with lock washers and nuts on the motor side. The base is small, so you may need needlenose pliers for tightening.

2b. Use a 2" hole saw in a drill press to cut wheels out of some scrap wood. I used 1×8 shelving and my finished wheels were ¾" thick by about 1.8" in diameter. Clamp the wood, and go slowly to avoid stalling the drill press.

2c. Center a wheel hub on each wooden wheel and use a small nail to mark 2 of the hole locations. Drill through the locations with a ⅛" drill.

2d. Paint the wheels. I love the Rust-Oleum red gloss; it is super thick, brightly colored, covers great, and cleans up easily. Try not to get too much paint in the mounting holes.

2e. Drill through 2 opposing holes in the hub with a #43 drill, then use a 4-40 tap to create threads in each hole.



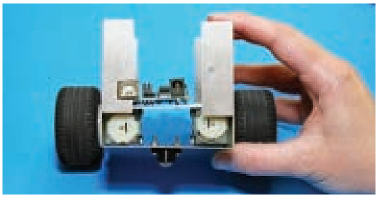
2f. Use two 4-40×1" screws to attach the wheels to the hubs from the outside. Don't overtighten.

2g. Install tires on the wheels, orienting them with the larger diameter facing out. Then snap each wheel assembly into its motor shaft.

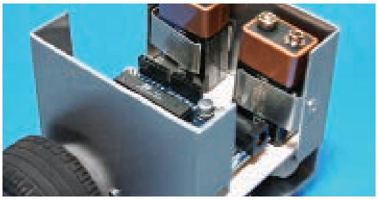
2h. Attach the skidder to the bottom of the base using the screws, nuts, and the thinner of the 2 spacers it comes with.

3. ADD THE POWER AND CONTROL

3a. Cut a plate out of hard plastic following the mounting plate template printed in Step 1a. Punch and drill it as indicated, then test-fit the plate into the robot body, resting on the motors, and file as needed for a snug fit. Use two 4-40×⅜" screws to fasten the Arduino board to the plate from the underside, securing it with nuts on top. The USB connector should line up with the notch in the tab.



3b. Pop-rivet the battery holders into the body through the holes in the left side tabs. Rivet from the outside so the ugly side of the rivet faces the battery.

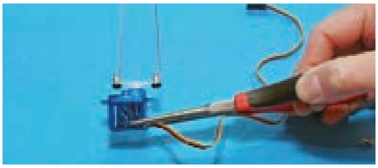


3c. Solder together the ProtoShield following the manufacturer's instructions, linked at makezine.com/19/makey. Use the band saw to slice off the board's BlueSMiRF header, which connects to Bluetooth wireless modules. Wasn't that fun? The header won't fit in the robot and we don't use it. Stick the mini breadboard onto the ProtoShield and plug the ProtoShield onto the Arduino. If you are using a Diecimila, set its power jumper to EXT.

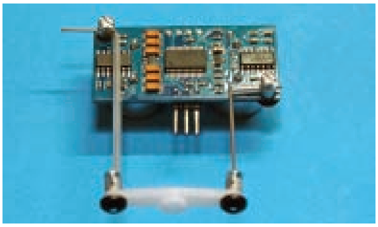
4. ADD THE SENSOR AND SERVO

4a. This project uses the shorter of the 2-arm horns that come with the HS-55 servo. Use a 1⁄16" bit to drill out the outermost holes in this horn.

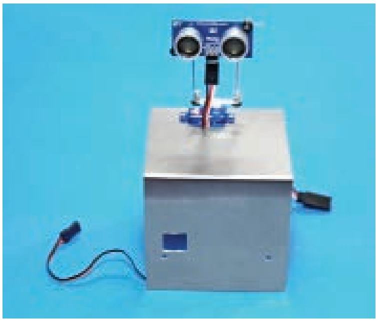
4b. Press-fit the metal pieces of the 2 Du-Bro Mini E/Z Connectors into the servo horn holes from the front, and secure them in back with the black rubber pieces. Thread the control rods from the Du-Bro Aileron System through the connectors and screw them down using the included screws.



4c. Here's a tricky part. Plug the servo extension wire into the Ping sensor board. Bend the control rods from the horn in opposite directions 90°, to reach mounting holes at opposite corners of the board. The rods will point up from the servo, allowing room for the extension plug, and the sensor should face out. Slip the pushrod housing that came in the Du-Bro package over the rods to avoid short-circuiting the sensor, then secure the rods to the board using the connectors from the aileron control kit.



4d. Thread the wires from the servo and sensor down through the rectangular cutout in the body's top piece. Fit the servo in the cutout, and fasten using two 1-72×1⁄4" screws and nuts through the holes on either side. Clip the excess control rod length. Screw the horn onto the servo and use a small screwdriver to adjust it so that Makey's eyes face forward.



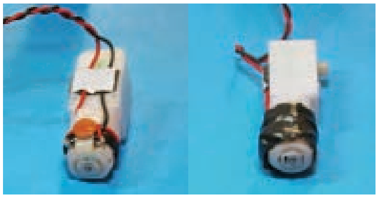
5. CONNECT AND TEST THE DRIVE MOTORS

The contact tabs on our inexpensive motors are fragile, so their connections must be strong and vibration-proof.

5a. Remove the motors and Arduino board from the robot body.

5b. Cut 2 red and 2 black 12" leads out of the stranded wire and strip 1" off an end of each. Without soldering, wrap each red/black pair around the round back end of the motor (for strain relief), then run the wires along the top and stick them on with a sandwich of double-stick foam tape. Don't cover any of the holes in the motor body, and leave room for the mounting nuts.

5c. Thread and solder the capacitor leads through the holes in each motor's connector tabs. This requires innovative bending with needlenose pliers. Then solder the motor wires to the capacitor leads, not the motor connectors, making a strong joint. Clip the extra lead length. Then cover the capacitor and the wrapped-around wires with black tape, and use more foam tape to cover the pointy bits.

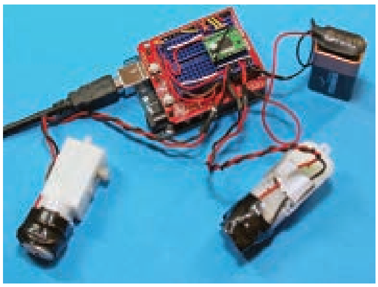


5d. Twist the free ends of the motor wire pairs together; this also reduces noise on the circuit. Mark the motors as Left and Right.

5e. Solder and heat-shrink short solid-core jumper wires to the drive motor and battery snap leads (this lets you plug them into the breadboard). Route the motor wires through the big holes in the plastic mounting plate.

5f. Plug the motor driver over the central trench of the breadboard and wire it to the drive motors and one battery, following the schematic. (Recall that on each side of the trench, holes in the same row are connected.) Use short jumpers to keep the wires close to the breadboard, as big loopy wires won't fit inside the robot.

5g. Download and install the Arduino software from arduino.cc and download the 5 project test programs from makezine.com/19/makey. Hook the Arduino to your computer via USB, and if it's a Diecimila, move its power jumper to USB.

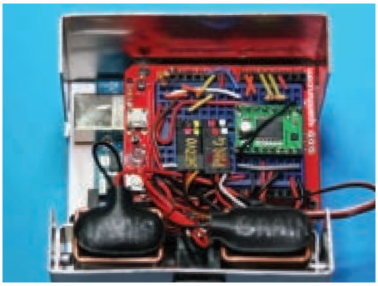


5h. To test the motors, run the program `01_Test_Motor_Rotation`. The left motor should run forward and back, followed by the right motor. If not, check your wiring. Next, run `02_Test_Motor_Speed`. The motors should start slow, speed up, and then reverse direction. Otherwise check wiring to pins D11 and D3.

6. CONNECT AND TEST THE SERVO AND SENSOR

6a. Replace the motors and Arduino assembly in the robot body. Plug a 3-pin right-angle header into the breadboard, plug the servomotor cable into it, and wire the servo: black to GND, red to +5V, and yellow to Arduino pin D10.

6b. Plug the other 3-pin header into the breadboard, then plug in and wire the rangefinder: black to GND, red to +5V, and white to Arduino pin D9.



6c. Run the program `03_Test_Servo_Center`, which centers the servo, then unscrew and realign the servo horn as close to center as possible. You can't get it exactly in the middle, because the teeth on the shaft won't allow it, but we can nudge it later in software.

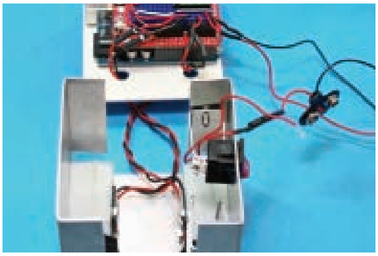
6d. Run `04_Test_Servo_Sweep`, which should make the servo slowly rotate from one side to another.

6e. To test the sonar rangefinder, run `05_Test_Sensor_Distance` and then click on the serial monitor icon in the Arduino software. You should see distance readings spitting out, and if you move your hand in front of the sensor, the readings should change. If your readings are stuck at 0cm or 255cm or otherwise incorrect, check your wiring, and make sure the sensor isn't plugged in backward.

7. CONNECT THE ARDUINO POWER

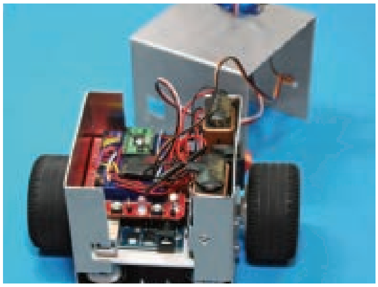
7a. Unpack the Arduino one last time. To add the on/off switch, solder the unused battery snap's red wire to one side of the switch and a solid red wire to the other. Also solder a solid black wire to the battery's black wire. Thread the wires out through the rectangular hole in the side of the robot body, and then press in the switch. Orient the switch with the "1" label at the top and fit it through the hole. It's a tight fit and you may need pliers.

7b. Wire the red lead from the switch to the RAW pin on the ProtoShield (which connects to Vin on the Arduino) and the black lead from the battery snap to the ProtoShield's GND pin. If you're using the Diecimila, move its Power jumper back to EXT.



8. BUTTON IT UP

8a. Now that all your electronics are working, carefully put everything back into the body without knocking loose any wires. Install the batteries and prop the robot up on something so it doesn't run off the table. The USB programming jack should line up with the cutout in the body.



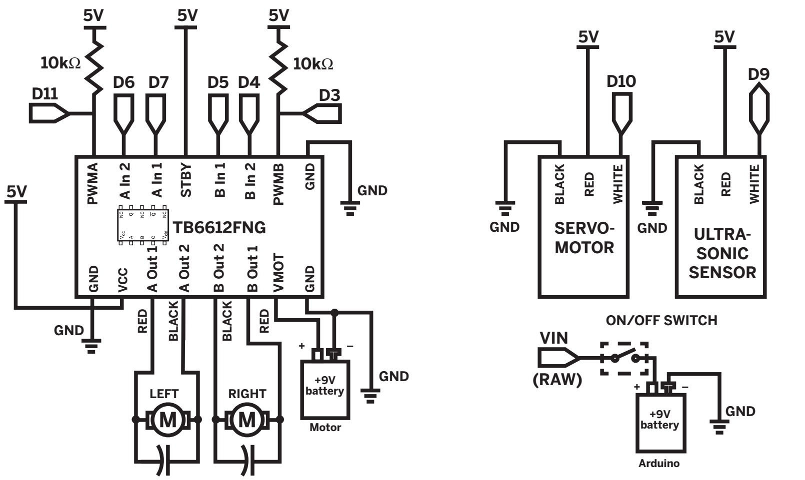
8b. Reload and run the test program `01_Test_Motor_Rotation`, noting that the front of the robot is where the USB jack and skidder are. If the motors rotate the wrong way, check your wiring to pins AOut1, AOut2, BOut1, BOut2, AIn1, AIn2, BIn1, and BIn2. You may also need to reverse the motor connections.

8c. Rerun the other test programs to make sure all the wiring is still OK. When satisfied, fold up the servo and sensor wires and tuck them into the base. Slide the top cover on, and install 4 sheet metal screws to hold it on. You're done!

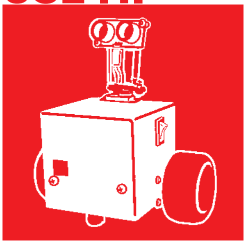
FINISH X

NOW GO USE IT »

SCHEMATIC DIAGRAM



USE IT.



ROLL YOUR OWN ROBOT

ROBOT PROGRAMMING

Sometimes when you're done building, you're done building — but you're never done programming. This is where you get to be creative, think of new things you want the robot to do, then write or modify programs to implement the behavior.

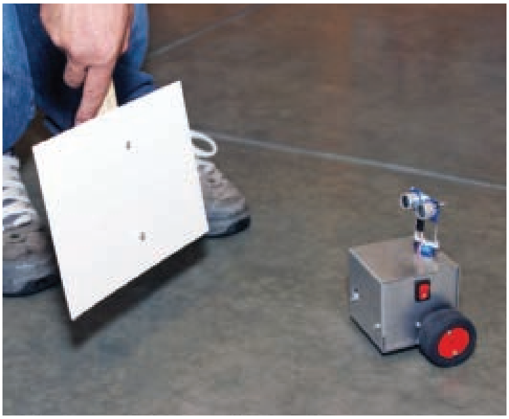
In the code, you control the motors by using the digitalWrite and analogWrite functions to pass values to pins on the motor driver, 3 for each motor. One pin takes a number 0–255 and sets the current sent to the motor, which determines its speed. The other 2 pins take binary values that set each motor contact to either high or low voltage. This sets the motor's direction (when only one contact is high) or turns it off (when both are low). For example, here's a subroutine for moving the robot forward:

```
void Forward()
{
 digitalWrite(leftDir1, LOW);
 digitalWrite(leftDir2, HIGH);
 digitalWrite(rightDir1, LOW);
 digitalWrite(rightDir2, HIGH);
}
```

You can write similar routines for the more basic motions, such as Backward (both motors backward), Spin_Left (right wheel forward, left wheel back), Arc_Left (right wheel forward, left wheel stopped), and so on. The Arduino programming environment makes it easy to experiment with code and load new programs to your robot.

Makey's object-following behavior based on proportional control is described on page 78.

Another fun behavior is object avoidance, which runs the loop: Move forward a bit, then take a distance reading. If the object is too close, take evasive action, such as back up and turn. Repeat.



Photograph by Ed Troxell

ROBOT MINI-SUMO

In a Mini-Sumo match, 2 autonomous robots are placed in a ring painted black with a white border. A robot wins when it pushes the other robot out of the ring (which means it has to find the other robot in the first place).

With narrower wheels, like the GM Series plastic wheels from Solarbotics (solarbotics.com/products/gmpw), Makey would fit within the maximum size and weight allowable for Mini-Sumo: a 10cm-square footprint and 500 grams. You would probably need another sensor pointed down to see the ring, but the Arduino has room for several more inputs.

RESOURCES

For more information about robot programming and behavior, I recommend *Robotics with the Boe-Bot* from Parallax, Inc. (parallax.com).

For the Makey project schematic, templates, and code see makezine.com/19/makey.

To see videos of Makey in action, visit makezine.com/19/makey.

ROK-BAK CHAIR

By Larry Cotton

ONE-SHEET WONDER

Can a chair be comfortable, look good, recline, disassemble for compactness and portability, and still be made from just a single sheet of plywood?

With a determination borne of frustration and frugality, I set about designing a chair that would meet all my requirements. I began by making a crude study model, with all body-supporting surfaces adjustable: the seat, the back, armrests, headrest, footstool, the angle between the seat and back, even the overall size. The model's only given: it would use a set of standard patio chair cushions and one sheet of plywood.

Somewhere in the middle of seemingly infinite adjustments, I discovered that recliners really are much more comfortable than upright chairs, so I threw reclinability into the mix as well.

Finally I found a combination that fits — ergonomically, esthetically, and economically. It's even been sleep-tested. I call it the Rok-Bak chair.

The Rok-Bak is very comfortable, easy and inexpensive to build, can be assembled or disassembled in a few minutes, and can be stored and moved about easily, taking up very little space.

Photograph by Sam Murphy

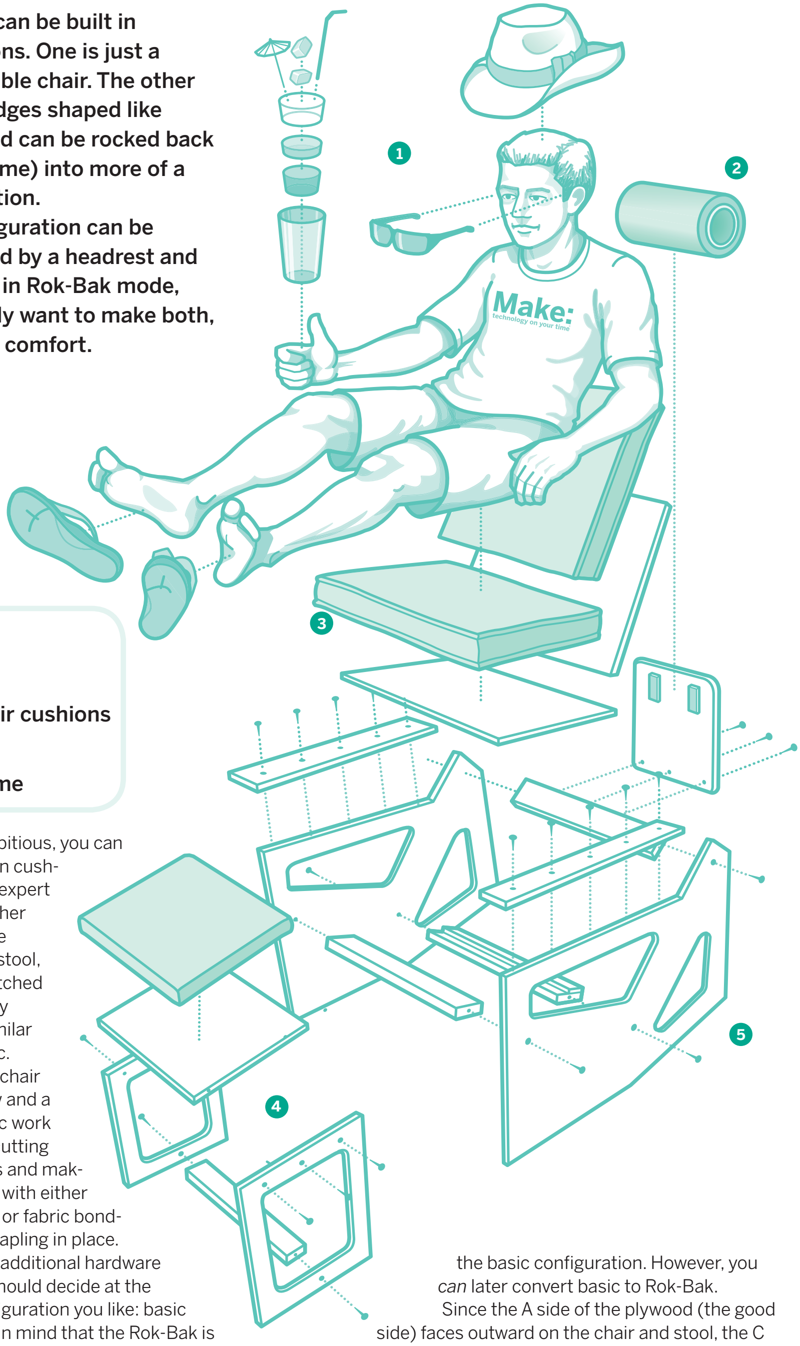
Set up: p.91 **Make it: p.92** **Use it: p.99**

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

A WORD FROM THE CHAIR MAN

The Rok-Bak can be built in 2 configurations. One is just a nice comfortable chair. The other has bottom edges shaped like shallow Vs, and can be rocked back (hence the name) into more of a reclining position.

Either configuration can be complemented by a headrest and footstool, but in Rok-Bak mode, you'll definitely want to make both, for even more comfort.



1. You
2. Headrest
3. Patio-chair cushions
4. Footstool
5. Chair frame

Illustration by Damien Scogin

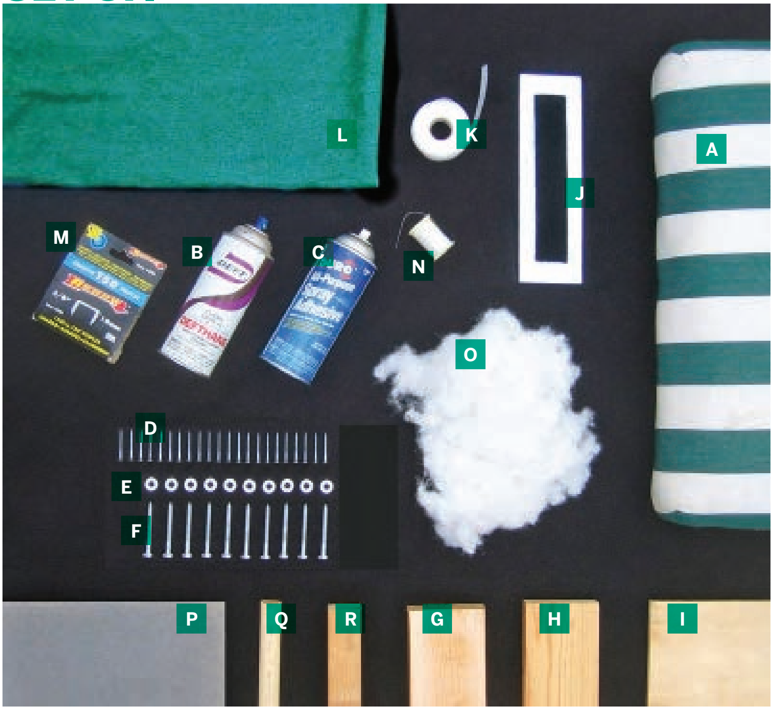
If you're really ambitious, you can upholster your own cushions (as I did with expert help from my brother Phil), as well as the headrest and footstool, for a perfectly matched set. The upholstery techniques are similar for most any fabric.

You can cut the chair parts with a jigsaw and a circular saw. Fabric work can be limited to cutting with good scissors and making 1 long seam — with either a sewing machine or fabric bonding tape — then stapling in place.

You'll also need additional hardware and staples. You should decide at the outset which configuration you like: basic or Rok-Bak. Keep in mind that the Rok-Bak is quite usable rocked forward. Once you cut the large bottom cutout, you can't change the chair back to the basic configuration. However, you *can* later convert basic to Rok-Bak.

Since the A side of the plywood (the good side) faces outward on the chair and stool, the C side, with its knots and other imperfections, will be almost completely hidden.

SET UP.



TOOLS

Jigsaw with plywood blade

Circular saw (optional) with plywood blade

Sander with various grits of sandpaper Random orbit is best.

Drill with drill bits and screwdriver bits

1½"–2" diameter drum-sander accessory for drill with 60-grit paper

7⁄16" ratchet wrench A manual ratchet is OK, but an accessory for your drill is faster.

Sharp pencils with erasers

Standard 15oz can You may eat the contents, but save the can.

MATERIALS

FOR THE CHAIR ONLY:

[A] **Patio chair cushions, 4"–5" thick (2)** stock or custom. Ideally get a 22"×40" stitched-together pair; alternately, get 2 separate cushions, each 22"×20". Big-box stores carry patio cushions, and fancier cushions can be found online in lots of colors and designs for a bit more money.

[B] **Varnish or polyurethane** spray preferred

[C] **Spray adhesive** for holding foam on arms during upholstery

[D] **#8×1½" flathead wood or drywall screws (22)**

[E] **9⁄32"–5⁄16" ID washers (10)**

[F] **¼"×2½" lag bolts (10)**

[G] **2×4 fir or pine, 8' length** for cross braces

[H] **1×4 fir or pine, 6' length** for arms

[I] **½" plywood, 4'×8' sheet, A-C interior grade (minimum)**

FOR THE FOOTSTOOL AND HEADREST:

[J] **Hook and loop fastening material (velcro), 30in²**

[K] **Fabric bonding tape, ½"–⅝" wide** such as Stitch Witchery. This is an alternative to sewing.

[L] **1yd of 54" or 60" upholstery fabric** Material for upholstery is abundant at mill outlets. I used denim for my deluxe chair, which looks good, is easy to work with, and (you guessed it) cheap.

[M] **Staples, with ⅜" leg (1 box)**

[N] **Spool of white thread (optional)**

[O] **4oz (minimum) pillow stuffing** such as Holofil or Nature-fil, for the headrest

[P] **Medium-density foam, 29"×19"×1½" thick** from a foam store or upholstery shop. Medium density weighs about about 1lb/ft³.

[Q] **1" wood dowel, 8½" length** for the headrest

[R] **2×2 fir or pine, 3' length** for footstool top supports

[NOT SHOWN]

¾" foam, 7"×25" or you can re-saw 1½"-thick foam

FOR UPHOLSTERING:

Scissors or shears

Electric knife (optional) for cutting foam

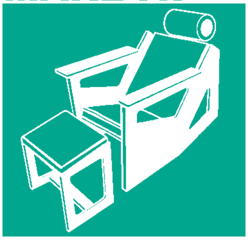
Band saw (optional) if you're re-sawing 1½" foam; otherwise buy ¾" foam

Staple gun

Sewing machine or clothes iron for sewing or hot-taping fabric seams

Photography by Larry Cotton

MAKE IT.



BUILD YOUR ROK-BAK CHAIR

START **Time:** A Weekend **Complexity:** Easy

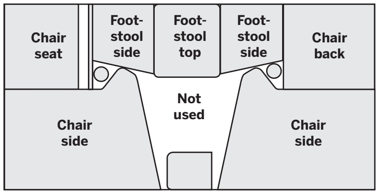
1. MAKE THE PLYWOOD PIECES

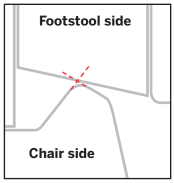
Download all the construction drawings at makezine.com/19/rokbak.

1a. Start by using a pencil to lay out the plywood pieces on the C side of the plywood. Why? Because we'll cut the parts out with a jigsaw (and possibly a circular saw), and we want to keep the A side (think "appearance" side) splinter-free. Both saws' blades cut on the upstroke, so any splintering will be confined to the (mostly hidden) C side.

You should lay out only one side of the chair and footstool. Later you'll use it to trace the other side, making sure they are mirror images, as shown in the layout drawing. Use a standard 15oz can as a radius (about 1½") template for corners. A sharp jigsaw blade should have no trouble following that radius.

To conserve plywood, you can skip laying out the footstool top. It can be pieced together later from the chair-side cutouts.





NOTE: You must cut the top corner radius of the chair side with a jigsaw; a circular saw would nick up the footstool side.

1b. Suspend your plywood on a few supports. Scraps of 4×4 wood or even paint cans (if they're the same height) make good supports. Position them, obviously, out of the projected path of the saw blade.

1c. Cut 1 chair side and 1 stool side. Start by jigsawing out the cutout under the arm. Drill a ⅜" starting hole from the C side — inside of, and close to (but not on), the layout line. Use a scrap of wood on the exit side of the hole to prevent splintering. Then insert the jigsaw blade into this hole and cut as usual.

NOTE: Both chair configurations begin with cutting out the sides as shown on the layout drawing. They can be used as-is for the basic chair. If you've decided to build the Rok-Bak, we'll cut the V-shaped bottom edges and bottom cutouts later.

It's a good idea to use a circular saw on the straight cuts, for speed, accuracy, and to minimize sanding. Notice that the gap between plywood pieces on the layout is at least ⅛". Thus one cut serves 2 pieces.

NOTE: You can minimize jigsaw splintering by using a splinter guard that snaps into the saw's footplate. Also, use new blades designed specifically to cut plywood, and if your jigsaw has multiple modes, set it to straight up-and-down rather than orbit mode. The cutting will go slower, but you'll get far fewer splinters.

1d. After cutting one each of the chair and stool sides, sand all the edges smooth. Use a sanding drum accessory in your drill if you have one; it will ensure nice, accurate, rounded corners that blend smoothly into the straight edges.

1e. Now trace around the finished sides onto the plywood sheet, as shown in the layout drawing and photos. Once more: you must lay out mirror images so that the good side of the plywood will face out on the finished chair. Cut out the remaining sides.

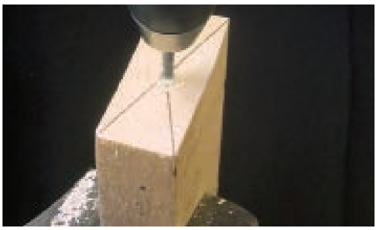
1f. Lay the chair sides face to face with the bad surfaces out, and drill the three ¼" holes for attaching the sides to the cross braces. To minimize splintering, place scraps of wood under the side where the bit will exit. Repeat this process for the mounting holes in the stool sides.

1g. Cut the chair's seat and back 22" wide to accommodate standard-sized patio chair cushions. For narrower cushions, adjust the widths accordingly. Add 3 countersunk holes to the back, following the layout.

1h. Cut out the footstool top and the headrest support, backstop, and disks.

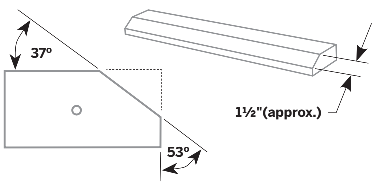
2. MAKE THE CROSS BRACES

2a. Next cut three 22" lengths of 2×4 for the chair. These will be cross braces A, B, and C. You'll modify A and B to accommodate the headrest and backstop. (Again, if your cushions are less than 22" wide, adjust the length of the 2×4s to match the width of the seat and back.)

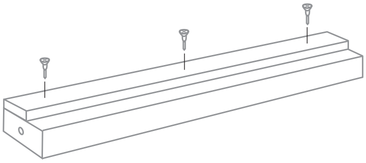


2b. After cutting, draw an X on all the ends of the 2×4s, corner-to-corner. At the center of each X, drill a 5⁄32" hole at least 2" deep.

2c. Cross brace A: If you plan to make a headrest, you need to shape a mounting surface for the headrest support piece. Using a hand or power plane, create a smooth, flat 1½"-wide surface, at least 10" long, at approximately the angles shown. (Easier would be to cut it on an adjustable-table band saw, for the entire 22" length of the brace.) The 53° and 37° angles ensure that the headrest support is vertical before the chair is rocked back.



2d. Cross brace B: Attach the backstop, a 22"×1¼"×½" strip of plywood that will support both seat and back pieces. This extra piece of plywood catches the bottom of the back, which then stops the seat. Use three #8×1½" wood screws, spaced approximately 8" apart.



2e. Cross brace D: For the footstool, cut a 15" length of 2×4 and drill holes in the ends as you did on the other braces. We'll make the other miscellaneous parts after test-assembling the chair.

3. ASSEMBLE THE BASIC CHAIR

3a. Prop the sides apart while you fasten the cross braces between them using the lag bolts and washers.

WARNING: Don't scrimp on the size of these bolts, or your chair and/or stool could disassemble itself dramatically! Before you add the seat and back pieces to the chair, check for smoothness of all surfaces and edges. This is not only an appearance issue, but an obvious comfort issue as well.

3b. Drop the back (3 screw holes up) and seat (any orientation) into their respective positions. Notice that the bottom of the back fits between the rear edge of the seat and the backstop on cross brace B. Do not sit yet!

3c. IMPORTANT: With the seat and back pieces flush with the wide side of all 3 cross braces, fasten the back to cross brace A with three #8×1½" flathead wood screws. These screws prevent braces A and B from rotating; your weight will keep brace C fixed.

3d. Now throw in a patio chair cushion set and give your chair a test-sit. The back cushion should rest on top of the seat cushion, whether they're a stitched assembly or separate cushions. I'm 5'11", 150lbs, and the chair fits me perfectly. If you're shorter, you can trim the sides along the bottom so that your feet will be well supported when you sit in the chair.

3e. If you're sure you want to build only the basic configuration, you can make the large bottom cutouts in the sides as shown in the plans at makezine.com/19/rokbak. However, if you're building the Rok-Bak version, leave the sides solid for now.

CAUTION: Don't be tempted to make cutouts in the sides under the seat. This will almost certainly make the chair too weak and wobbly.

4. MAKE AND ATTACH THE ARMS

The only thing tricky about adding arms to the chair is the mounting itself. Each side of the chair will be taking 5 screws 5" apart, exactly centered in the top edge, which is ½" wide. Be careful: if these holes aren't drilled properly, the drill bit could break out the side.

4a. You can control your drill bit better if you make a drill bit guide. It can be a piece of sheet metal, bent at a right angle or attached to a wood block. In any case, drill a ⅛" guide hole so that when using the guide, the guide hole will be exactly in the center of the plywood edge.

4b. Draw lines on the top edge of the chair sides, then using the drill-bit guide, drill 5 holes straight down into each side.

4c. Make the arms from 1×4 fir or pine. If you plan to pad and cover the arms, this wood doesn't need to be the best quality, but if you'll leave it exposed, choose decent pieces of solid wood.

4d. Now position an arm with the front of it overhanging the front of the chair side by ½". This overhang is necessary for stapling the fabric if you pad the arms. Mark the bottom surface of the arm to line up with the holes drilled in the top of the side. Drill the screw clearance holes from the bottom, which should ensure that the screw holes line up exactly. Repeat for the other arm.

4e. Countersink the screw holes from the topside of the arms so the screws will be slightly sub-flush. Mount each arm with five #8×1½" flathead wood screws.

NOTE: If you don't want to pad the arms, you could round the top-front corners of the arms with a ¼"-radius router bit, or just sand something close. If you *do* want to pad the arms — highly recommended for comfort and appearance — that will be the very last step in building the chair (Step 8b).

5. MAKE THE FOOTSTOOL ASSEMBLY

If you're making just the basic chair configuration, you can survive without a footstool. But for extra comfort, especially with the Rok-Bak, you'll need one.

5a. Cut the parts and assemble the sides and cross brace D. You can make the top as 1 piece (see layout) or piece it together from cutout material (as shown here). Assemble the top and the 2×2 runners.

5b. You can throw a pillow on the stool and help it stay in position with velcro, but covered padding looks more professional. Either way, the pillow or covering fabric should match your chair's cushions (if they're striped, you might choose a solid that's one of the stripe colors).

5c. If you're padding, cut 1½"-thick foam to match the top exactly. A band saw or electric knife works well. Cut the fabric about 4" oversize on all sides, pull it reasonably tight (the foam should compress slightly), and staple it in place. Miter the corners. Use a minimum of staples at first, then add more as necessary to keep the fabric evenly taut, the foam reasonably compressed, and the corners neat. Trim as shown.

6. MAKE THE HEADREST

A well-padded headrest is key to a comfortable chair. Cover it with the same fabric you used for the footstool. For attaching the finished headrest to its support, you'll sew on velcro at least 1" wide. Adhesive velcro doesn't stick well enough to fabric.

6a. Cut the fabric to 22"×22". Secure the seam and velcro strip. You have a choice of sewing or using fabric bonding tape. Use a sewing machine if you can. However, I found that Stitch Witchery tape makes a surprisingly strong seam, at least on denim.

If you're sewing, sew an 8" velcro strip to the visible side of the fabric, about 1" from one edge, centered. Sew all the way around the velcro.

Fold the fabric in half, wrong side out, and sew a 22" straight seam about ½" from the open edges. Turn the fabric sleeve right side out. It should be about 7" in diameter.

If you're taping, fold the fabric in half, wrong side out, and place a 22" length of Stitch Witchery tape between the open edges. Follow the instructions on the package; the operative words are hot and damp. The joint must be steamed to be strong (don't forget the damp cloth). Let it cool before testing. Turn the fabric sleeve right side out. It should be about 7" in diameter. Place the 8" velcro strip adjacent to the seam (on the outside of the sleeve), with one or more strips of bonding tape between the velcro and the fabric. Iron the fabric side, not the velcro side. This means you must put the iron in the sleeve.

6b. Cut a piece of 1½" foam 19"×12". Tightly roll up the foam from the short end, insert it into the fabric sleeve, and let it unroll. About 5" of the sleeve (22" − 12" = 10"/2 = 5") will overhang each end. The 2 ends of the foam should butt together inside and be "circularizing" the sleeve.

6c. On one end, poke the surplus fabric over the foam and into the center hole. Cut the wood dowel and drill both ends as shown. Attach one 4¼" disk to the end of the dowel with a 2½" lag bolt and washer.

6d. Press the dowel-disk assembly, dowel first, into one end of the cylinder. Gather the material as you press, and space the folds neatly around the inside circle. Stop pressing when the outside face of the disk is about 1½" from the end.

6e. From the other end, stuff at least 4oz of Holofil or other stuffing between the dowel and the inside wall of the cylinder. Hold the other disk to keep it from being pushed out the end. Try to fill all voids, keeping the dowel in the center. The more stuffing you can push in, the more comfortable your headrest will be.

6f. Fold the surplus material over the foam at the other end.

6g. Put a lag bolt and washer through the hole in the second disk, then push the tip of the bolt into the hole in the end of the dowel. Tip the disk inward and press it into the foam core, keeping the fabric as neat as you can. You can press the other end's disk in a little farther to make it easier.

6h. Tighten the second lag bolt with a ratchet wrench, while holding the first bolt with pliers. Neaten your fabric folds at both ends.

6i. Staple 2 small strips of velcro to the headrest support near the top, so their outside edges are 8" apart.

6j. Mount the support to the bevel on cross brace A, exactly in the center, with three #8×1½" screws. Temporarily stick the headrest to the velcro strips on the support and give the chair another test-sit.

7. OPTIONAL: CONVERT TO ROK-BAK VERSION

To allow the chair to rock back, the bottoms of the sides must be cut into shallow Vs. The tipping point of the V is critical. Your Rok-Bak chair must:

» be completely stable when rocked backward; do not exceed the 5½" rocker dimension on the drawing.
» stop, with a small thump, in the reclined position.
» not lean prematurely; it should require a light push with your feet, but not be difficult to rock backward.

7a. Temporarily disassemble the chair so that you can make identical, accurate cuts (preferably with a circular saw) on the bottom of each side. Make it a shallow V, and if you're about the same height and weight as me (see Step 3d), you can make the bottom cuts as dimensioned here.

7b. If you're of a different build, you should make a few trial cuts and reassemblies, taking longer and longer cuts until you arrive at the right balance. **IMPORTANT:** You must not exceed the 5½" rocker dimension for safety and stability! After each pair of cuts, reassemble the chair — with cushions, headrest, and arms — and try it. You'll get pretty good at loosening and tightening lag bolts. (Use a 7⁄16" hex driver in your drill to speed things up.)

NOTE: All is not lost if you cut too much off; you can always take a little off the front legs of the Vs to make them longer.

7c. Once you get the tipping point right, you can finally make the bottom cutouts in the sides. This will cause the chair to be slightly more stable in the forward position, which may turn out to be a good thing.

Draw the cutouts (on the C side, remember?) of both chair sides, using the 15oz can as a radius guide. For strength, it's important to keep the bottom of the cutouts at least 2¾" from the bottom edge of the chair. Carefully make the cutouts with a jigsaw.

8. FINISH THE WOOD AND PAD THE ARMS

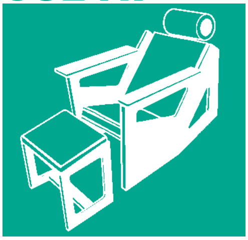
8a. Remove the cushions, headrest, seat, and back. You don't have to disassemble the chair. Sand all exposed surfaces down to about 120-grit paper, then spray (or brush, if you must) with varnish or clear polyurethane, such as Deft. Several coats, lightly sanded between each, usually yield a nice finish.

8b. Finally, to pad the arms, cut ¾"-thick foam to the size of the arms (you can also use 1", or you can rip 1½" in half with a band saw), and lightly mount it with spray adhesive or double-sided mounting tape. Cover the arms with fabric that matches the footrest and headrest. Trim the underside neatly.

FINISH X

NOW GO USE IT »

USE IT.



MAKE YOURSELF COMFORTABLE

USE AT YOUR OWN LEISURE

Now drop in your cushions, stick the headrest on, and pull up the footstool. Take a seat and make yourself comfortable.

As you would with any rocking chair, watch out for the cat's tail, then rock back and dream of your next project: adding speakers to the headrest.

AMERICAN ORIGAMI

Like origami, single-sheet plywood projects transform a standard plane into countless 3D objects. Generations of designers have worked within this form, laying out cleverly fitted pieces that make furniture and toys with little or no wasted wood.

RESOURCES

+ For a materials and tools list, plans, and diagrams: makezine.com/19/rokbak.

Custom patio chair cushions: customcushions.net, patioshoppers.com

The green-striped cushion I used: makezine.com/go/greenstripe

How to use Stitch Witchery fabric bonding tape: makezine.com/go/stitchwitchery

How to cut foam: makezine.com/go/cutfoam

Photograph by Sam Murphy

SPEED VEST

By Mykle Hansen

SPEED READING

This lightweight night-cycling vest displays your current speed in glowing, 7-inch-tall numbers easily visible to cars. On the back, an Arduino microcontroller reads input from an off-the-shelf bike speedometer sensor, and then switches power to sewn-in numerals made from electroluminescent (EL) wire.

Bicyclists receive a lot of honk-based grief from car drivers who perceive them as slow and in the way, and when drivers misjudge a bicycle's speed, it can cause "right hook" collisions that kill several bicyclists each year. If car users knew how fast cyclists were moving, would they be more willing to share the road? What if a bicycle prominently displayed its speed to the cars behind it, using large, brightly lit digits?

Brady Clark, cycling advocate and design genius, asked me to help him answer this question. At first I assumed it was beyond me, since I was a software guy who barely understood electronics. But I love to learn, and the Dorkbot community in Portland, Ore., was encouraging and helpful.

Our final motivation was the Bike Gadget Contest in Minneapolis, sponsored by the Bell Museum and The Hub, a bike co-op. After some research and shopping, we completed this project in a manic three-day push, then delivered it to the contest judges within minutes of the entry deadline.

Photograph by Noah Webb

Set up: p.103   Make it: p.104   Use it: p.109

Mykle Hansen lives in Portland, Ore., with his family, cats, chickens, and a basement full of contraptions. He is usually writing, bicycling, or playing the drums.

HEADS-UP DISPLAY

The Speed Vest is based on an Arduino microcontroller running software that reads pulses from a standard bicycle speedometer sensor and then routes power to the EL wire display accordingly.

Illustration by Timmy Kucynda

① The speedometer sensor on the bicycle's frame detects each pass of a small magnet mounted to a spoke.

② With each pulse, the Arduino microcontroller calculates current speed by dividing the wheel's circumference by the time since the last pulse. Then the Arduino converts the speed to mph (or kph) and turns on its output pins to show the number, for example 2 on the left and 3 on the right to indicate 23mph.

③ The Nixie-style digits are made from electroluminescent (EL) wire, which consists of a solid wire core coated by a phosphor material and wrapped around with fine wire mesh. When you connect the core and the outside wires to high-voltage, high-frequency AC, the phosphor glows.

The digits are sewn onto a vest, but the wire is too thick to overlay all 10 possible digits in one position, so the tens place displays 0 to 6 and the ones place shows only odd numbers. This makes for a maximum speed of 69. If your speed ends in an even digit, we round it downward.

④ The Arduino can't deliver enough voltage to drive EL wire, so its outputs control triacs, solid-state switches that route power from a power supply. Triacs can look like regular transistors, but instead of amplifying directional DC, they open a bidirectional connection that can carry AC.

⑤ The power supply is a small inverter that converts 1.5V DC from a AA battery to 125V AC at 2,000Hz.

⑥ A ribbon cable connects the electronics to the vest.

SET UP.

Photography by Ed Troxell

MATERIALS

[A] Vest We chose the Mil Spec Mesh Vest, $55 from Icon (rideicon.com), a high-visibility motorcycling vest with a handy rear pocket to hold the electronics.

[B] 26-gauge stranded insulated 2-conductor wire

[C] Arduino ProtoShield kit $16 from the Maker Shed (makershed.com)

[D] Arduino USB microcontroller $35 from SparkFun Electronics (sparkfun.com) or the Maker Shed

[E] Buttoneer with refill pack of plastic fasteners or a needle with monofilament thread. The Buttoneer is $12 from fabrics or sewing supply stores.

[F] Black denim or thick cotton cloth, 12"×12"

[G] Small box to house the control circuit and wires.

[H] Triacs, 0.8 amp, 400 volt (8) Digi-Key part #MAC97A6OS-ND, digikey.com

[I] ⅛" heat-shrink tubing

[J] Resistors: 100Ω (12), 1kΩ (1)

[K] Safety pins or velcro tape

[L] Wheel sensor from a wired (not wireless) bicycle speedometer (aka cyclo-computer) The sensor must perform like a reed switch, which is binary, rather than use the magnet on the spoke to vary the inductance. We used a Sigma Sport BC 500, which costs $15, but the city of Portland gives them to residents free, to encourage bicycling! Ask a bike shop if they can sell you just the wheel sensor part, without the computer and display.

[M] Batteries: 9V, 1.5V AA

[N] 2×7 male header

[O] 14-wire ribbon cable with 2×7 pin female plug

[P] White EL wire, 2.5mm, 20' $20 from CooLight (coolight.com). You'll need 12 segments of wire, 16" long with 10" leads. If you don't want to cut and solder your own, the folks at CooLight can do it for $2.50 per segment. Also available at Light 'n Wire productions (lightnwire.com).

[Q] Foil tape (optional) if you cut your own EL wire

[R] EL wire power supply We used CooLight part #CL-IPSF3, $6, which takes 1 AA battery and can light EL wire segments up to 16" long.

[NOT SHOWN]

Reflective tape, 3"×12" We used 3M Scotchlite Iron-On from identi-tape.com. Or use sew-on reflective letters from searchgear.com.

Electrical tape

TOOLS

[S] EL wire stripper (optional) if you cut your own EL wire

Computer with a USB port

USB cable

Soldering station and solder

Needlenose pliers

Multimeter

Scissors

Rigid plastic or cardboard, 9"×7" sheet

X-Acto knife

Lighter

Print Gocco screen printing kit (optional) available on eBay

MAKE IT.

BUILD YOUR SPEED VEST

START **Time:** 1-2 Weekends **Complexity:** Moderate

1. ASSEMBLE THE PROTOSHIELD

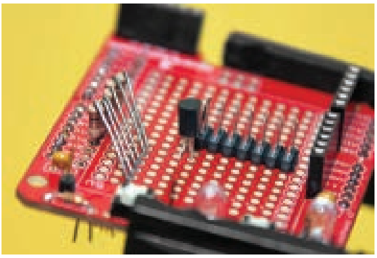
The ProtoShield lets you build circuits directly on top of the Arduino board. I assembled it following Atomicsalad's excellent ProtoShield tutorial, linked at makezine.com/19/speedvest.

If you're really in a hurry, you can leave out all the female headers. But if you might use your ProtoShield for other projects later, it's better to assemble the whole thing (and you'll still have to do a lot of desoldering.)

2. BUILD THE CONTROL CIRCUIT

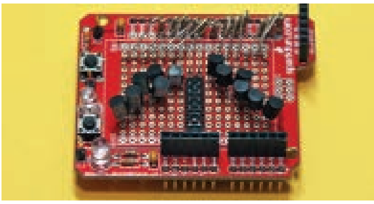
For each display digit, an Arduino output pin connects through one resistor to one triac. The other 2 pins of the triac connect to ground and the digit's ribbon cable pin. It's a simple circuit; the tricky part is fitting 12 of them onto the ProtoShield. (There are too many connections to use the ProtoShield's mini solderless breadboard.) Here's how I did it. Refer to the schematic at makezine.com/19/speedvest for all connections.

2a. Plug the 2×7 male header across the middle of the board, perpendicular to the rails and with one end adjacent to the ground (GND) rail.

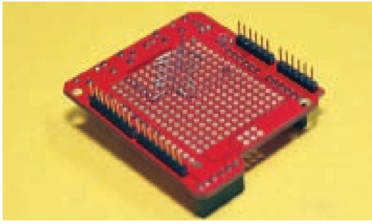


2b. Plug in the 100Ω resistors just below the 5V rail in 2 rows of 6, grouped on either side of the male header. Underneath, connect one end of each to one of the D0–D13 contacts, on the female headers if present, or else on the board itself. Leave D3 empty for the speedo interrupt. To save room, orient the resistors vertically.

2c. Arrange triacs at the intersection of each resistor and header pin. For each triac, the gate lead (pin 2, the middle pin) will connect through a resistor to one of the Arduino's digital outputs D0–D13. This pin controls the flow between the other 2, like the base of a transistor. Pin 1 of the triac, on the left as you read the printing on its face, connects to ground, and pin 3 connects to the ribbon cable via the 2×7 male header.



2d. On the underside of the board, connect the resistors, triacs, and ribbon cable header following the schematic. I simply bent and soldered down the uncut leads, rather than the usual method of trimming leads and connecting with insulated wire. Apologies to any professional electrical engineers who are nauseated by this.

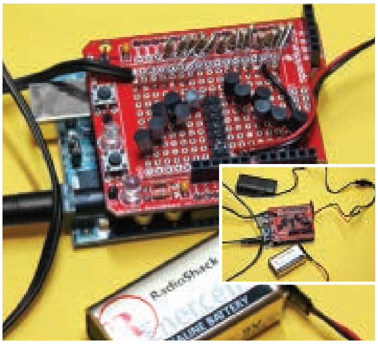


2e. Connect the speedometer sensor's 2 wires to power (5V) and one of the Arduino's interrupt pins, D2 or D3 (I used D3). Also tie that same pin to ground with the 1kΩ resistor; otherwise, your sensor might detect nonexistent ghost bikes in your vicinity. Different ProtoShields have different layouts, so you should make these connections wherever it makes sense for your board.

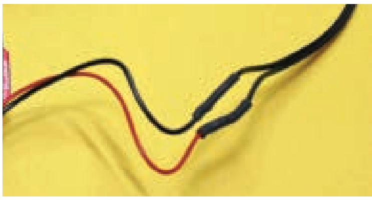
On the one shown here, made by MAKE intern Kris Magri, the speedo connects to one end of the 5V rail and an adjacent hole, which is wired up to D3 on the underside. The 1kΩ resistor fits into the row of 100Ω resistors and connects to ground.

On my v.1 ProtoShield, the power, ground, and D3 pins all sit on the BlueSMiRF header, so I plugged the speedo in there. This project doesn't use Bluetooth, and the BlueSMiRF header was a handy place to connect.

2f. Connect the EL wire power supply's black wire to the board's ground rail and its red wire to both adjacent pins at the end of the ribbon header, bridging the 3 pads underneath. This divides the power so that one ribbon wire feeds the left digit and the other feeds the right.



2g. Use electrical tape to insulate all exposed conductors, and shrink any heat-shrink tubing you've applied.



2h. Solder one lead from each digit (either lead) to individual wires of the ribbon cable. These are the grounds. You can be systematic and plan ahead which pin goes to which numeral, but we decided not to keep track and to make the associations later in the software.

3. TEST THE CIRCUIT

3a. Download and install the latest Arduino software from arduino.cc. On older versions of Mac OS X, you may also need to install the provided USB Serial Driver, so that your computer sees the Arduino as a serial port.

3b. With the ProtoShield unplugged, hook the Arduino to your computer. Download and run the "Blink" example code, on the Arduino site under "Learning/Examples," to prove that your whole toolchain works.

3c. Download the test software, *Test_EL_Digits.pde*, from makezine.com/19/speedvest. Plug the ProtoShield into the Arduino and the ribbon cable into the ProtoShield.

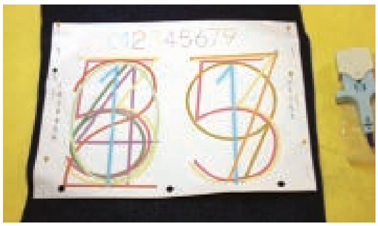
3d. Run the test software, which cycles through each output pin in order, so you can spot any bad connections. Quality control and breakage can be an issue with EL wire, so handle it gently and make sure each segment works. One bad segment can short out the whole circuit, in which case you should check the resistance across all of them.

4. BUILD THE DISPLAY

4a. If you're working with plain EL wire rather than prepared segments, you need to connect leads to the core and wrap wires of each piece. Cut the EL wire into 16" segments, and burn off 1" of the outer sleeve at one end to expose the wrap wires. Make 12 of these segments. To make a solderable contact for the wrap wires, you can carefully tease them to one side and twist them together, or else belt them with a snug loop of copper tape. Then use a knife or stripper to remove the phosphor underneath and expose the core wire.

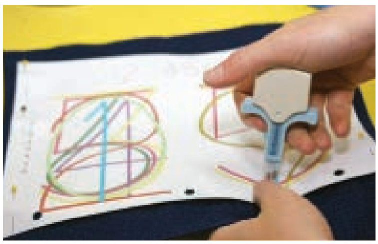
Split and strip a dozen 10" leads, then solder the EL core and wrap wires to separate lead wires. Use heat-shrink tubing to insulate and reinforce the joints, remembering to slip the pieces over the leads before soldering.

4b. Download the digit template *stacked_numbers_template.pdf* from makezine.com/19/speedvest, print it, and pin it to the 1' square of thick black cloth.

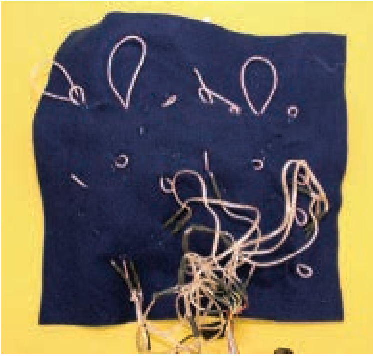


4c. Pin the cloth around a frame of plastic or cardboard, then run strands of EL wire along the path of each digit, entering and exiting through holes cut in the backing cloth at the bottom of each numeral.

To anchor the EL wire to the fabric, we used a great tool the CooLight folks hipped us to: the Buttoneer. It's designed to attach buttons to clothes using small plastic staples, but it also works brilliantly for attaching EL wire.



EL wire can't take sharp bends without breaking. To create the hard corners that discerning digit-users crave, run it out the back through a hole, loop it around underneath, and bring it back up at the different angle.



4d. Once the digits are affixed, rip away the paper underneath, bit by bit.

4e. Trim any excess EL wire off the digits. If you're using precut segments, move the end caps onto the new ends; otherwise, cap the ends with a bit of heat-shrink.

4f. For the other, non-ground leads, twist them together into a single mass on each side of the ribbon cable and solder them to the 2 pins that connect to the power supply.

5. CONFIGURE AND RUN THE SOFTWARE

5a. Download and run the Speed Vest software, *speedo_4.pde*, from makezine.com/19/speedvest as in Steps 3c–3d. When the program starts, it cycles through each output pin in order, so you can identify which pin feeds to which digit. At this point the numbers should light up in random order.

5b. Unplug the ProtoShield and use a multimeter to probe and map the connections between the Arduino output pins and the digits. Then edit the array definitions for `onesPins` and `tensPins` at the top of *speedo_4.pde* to reflect the associations. Edit and rerun the software as needed until the numbers boot up in order.

5c. Test the system on the bench by holding the 2 halves of the wheel sensor and brushing the magnet past the switch in a regular rhythm, to simulate the rotation of a wheel. At this point, we found it very gratifying to see our work light up!

6. ASSEMBLE THE VEST

6a. Now attach the hardware to the vest. We used velcro tape, but with hindsight I recommend you sew it or use plain old safety pins. They're cheaper and more secure, and we haven't yet needed to remove and reconnect the display.

6b. (Optional) Brady used his beloved Print Gocco miniature screen-printing kit to add some extra safety-bling to the vest: a reflective "MY SPEED" banner to run along the top. You could also just use reflective paint or tape.

7. OOPS! QUICK — BUILD A CASE! (DUH!)

It's stunningly un-chic to have dangly bits of electronics trailing out behind your butt, or tangled in your spokes. But somehow, we failed to foresee the obvious need for a case. Under extreme deadline pressure, our original Speed Vest had a ghetto-tech case made from scrap cardboard and rubber bands.

For the version shown here, built by Kris from MAKE, she used a plastic soap dish, and then after that disappeared from the lab, she tucked it into a small box. The case just fits into the pocket of the vest, so it isn't visible, but I'll still bet you can do better!

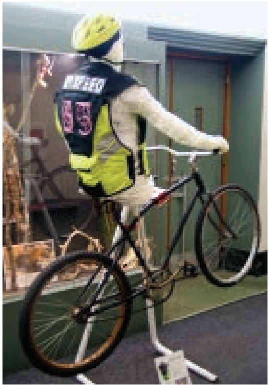
We ran the ribbon cable through a tiny slit in the integrated rear pouch of our vest. The case fits snugly in the pouch, hiding all our sloppiness while letting our invention shine!

» *Special thanks to Nick Sanders at West County Cycle Service for his help with our build.*

USE IT.

GLOW, SPEED RACER

THE DISPLAY MANNEQUIN



With less than 12 hours remaining before our all-motivating contest deadline, we began work on our floor display. We made a mannequin to wear the Speed Vest by casting Brady, using Mark Jenkins' packing tape sculpture technique (tapesculpture.org). Add one bicycle and one bicycle work-stand, and we were ready to wow the public.

SPEEDVEST II

It's hard to know just how car drivers feel about the Speed Vest, but so far nobody bicycling while wearing it has been honked at or run over. Meanwhile, we're now working on SpeedVest II, with four major areas of improvement:

» **Wirelessness** If the rider forgets he's plugged into the bicycle when he dismounts, the electronics get yanked. In practice, this happens almost every time, and we've had to resolder the connectors three times already. SpeedVest II will use Zigbee wireless modules to transmit speed data from the wheel to the Arduino.

» **Size** In bicycle equipment, lightness is everything. The Arduino USB board is handy, but contains a lot of parts we don't use. With a custom PCB design, we can get the whole system much smaller and lighter.

» **Power** The Arduino is powered by a 9V battery, but the EL wire inverter has its own AA battery and a separate power switch. The batteries run out at different times, and turning the unit on and off is a two-step process. Our improved single-board design will integrate the inverter, driven from the same power source as the rest of the board.

» **Speed range** Bicycles are fast, and getting faster! Our vest displays speeds up to 69mph, but the current bicycle land speed record is 81mph. (And that's not even close to the drafting speed record of 152mph, set by a bicyclist chasing a specially designed car that pushed away the forward wind resistance.) So we're redesigning our numeric display to show all speeds from 1 to 99 miles per hour. We hope that will suffice for normal use.

THE CONTEST

We handily accomplished our first mission: winning The Hub's Bike Gadget Contest. W00t!

Then we set about testing the Speed Vest in real traffic. We've had great success with it, and the feedback from everyone who's seen it has been wonderful. Many people want their own.

Also, simulating a wheel with your hands, and seeing how fast you can make the speed display go, has become a strangely compelling party game.

RESOURCES

Download all project code, schematic diagrams, and templates at makezine.com/19/speedvest.

Keep up with the Speed Vest project at speedvest.com.

Photography by Mykle Hansen

1+2+3 Batteries from Everyday Things By Cy Tymony

No one can dispute the usefulness of electricity. But what do you do if you're in a remote area without AC power or batteries? Make sneaky batteries, of course! And once you know how to make sneaky batteries, you'll never again be totally out of power sources.

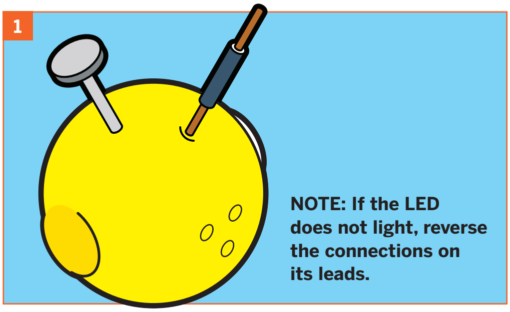
YOU WILL NEED

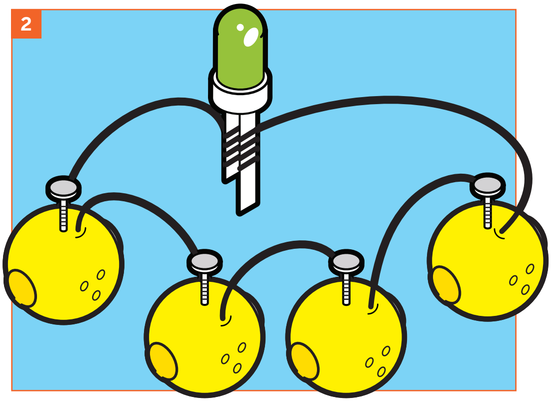
- Lemon or other acidic fruit
- Nail, paper clip, or twist-tie
- Heavy copper wire
- Water
- Salt
- Paper towel
- Pennies and nickels
- Plate

1. The Fruit Battery

Insert a nail or paper clip into a lemon. Then stick a piece of heavy copper wire into the lemon. Make sure the wire is close to, but does not touch, the nail (Figure 1). The nail has become the battery's negative electrode and the copper wire is the positive electrode. The lemon juice, which is acidic, acts as the electrolyte. You can use other electrode pairs besides a paper clip and copper wire, as long as they're made of different metals.

The lemon battery will supply about ¼ to ⅓ of a volt of electricity. To use sneaky batteries to power a small electrical device, like an LED light, you must connect a few of them in a series, as in Figure 2.





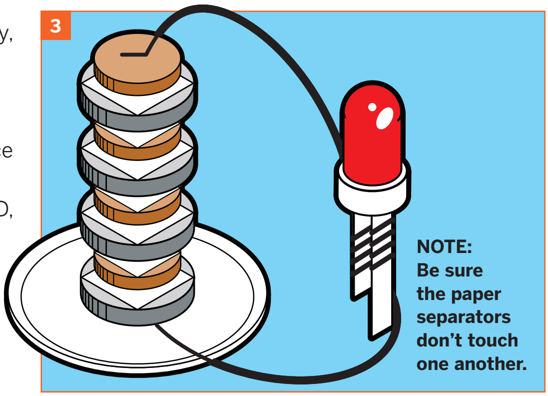
2. The Coin Battery

With the fruit battery, you stuck the metal into the fruit's electrolyte solution. You can also make a battery by placing a chemical solution between 2 dissimilar metal coins.

Dissolve 2 tablespoons of salt in a glass of water. This is your electrolyte solution.

Now moisten a piece of paper towel in the salt water. Put a nickel on a plate and put a small piece of the wet absorbent paper on the nickel. Place a penny on top of the paper. Next, place another moistened piece of paper towel on top of the penny, and then another nickel, and continue the series until you have a stack.

The more pairs of coins you add, the higher the voltage output will be. One coin pair should produce about ⅓ of a volt. With 6 pairs stacked up, you should be able to power a small flashlight bulb, LED, or other device (Figure 3) when the regular batteries have failed. Power will last up to 2 hours.



Excerpted with permission from Sneaky Green Uses for Everyday Things *by Cy Tymony, Andrews McMeel Publishing, 2009.*

Illustrations by Julian Honoré

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

KUSTOM TONKAS

Turn a classic toy into a hot rod for kids of all ages. By Todd Lappin

In my house, we have a tradition: whenever a friend or family member has a firstborn child, we present the lucky parents with a brand new Tonka dump truck. Boy or girl, it doesn't matter — have a kid, and you get the truck. We've given dozens away over the years. Kids still love 'em, and no wonder: Tonka's classic dump truck is big, durable, fun, and extremely yellow.

When it was our turn to have a firstborn, I wanted to create a Tonka that was extra special. We were expecting a daughter, so I hit on the idea of giving her a pink Tonka. And not just pink; I wanted to give her a pink Hello Kitty Tonka, a slick mashup of two childhood icons! No child of mine could possibly go through life without one.

Happily, the venerable Tonka dump truck turns out to be a versatile platform for mods and customization. I started by building a prototype: a primer-black truck with red wheels that I nicknamed the Rat Rod Tonka. I liked it so much that I brought it to a local pinstriper to add some fancy scrollwork. The Hello Kitty Tonka came next, and I really liked the way it turned out too (to see all the Tonkas to date, go to

MATERIALS AND TOOLS

Flathead screwdriver
Electric drill, 7/32" drill bit
Hammer
Masking tape roll or similar
3/8" sockets (2) like from a hex socket set
LocTite thread-locking compound
Machine screws with washers and nuts (2) to replace drilled-out rivets
Very fine grit sandpaper or a finishing sander wheel
Spray paint, Goo Gone
Contact paper or automotive decal sheet

Photography by Todd Lappin

makezine.com/go/tonka). There are more I still want to build — a Tonka lowrider! a Tonka painted like the Partridge Family bus! — and I'll make them all eventually, but in the meantime you may have even better ideas. Here's everything you need to know about creating your own Kustom Tonkas.

1. Buy a classic Tonka dump truck.

This isn't as easy as it used to be. Hasbro, the company that owns the Tonka brand, recently created an all-new Mighty Dump Truck. The new model is bigger, more modern-looking, and a bit more expensive. The older one — which employs the same basic design Tonka has used since 1964 — is still offered, but like old Coke, it's now marketed as Tonka Classics (Figure A), and it's getting harder to find. Fortunately, most Toys "R" Us stores still carry the Tonka Classics Dump Truck right alongside the newer model, for the bargain price of about $20. Cheap!

2. Deconstruct the truck.

Tonka dump trucks are famously rugged, and much of their strength comes from the simplicity of their design. All you need to take one apart is a flathead screwdriver and an electric drill. Here's how to do it:

2a. Remove the wheels. Use a long, thin, flathead screwdriver to gently but firmly pry the chrome cap off one end of each axle (Figure B). Start by wedging the blade under the cap, then roll it side-to-side to loosen the end cap. Try to avoid bending or mutilating the caps, because you'll replace them later when your ride is ready for reassembly. Save the caps and axles in a safe place, so you don't lose them.

2b. Remove the tires from the wheels. There's no glue holding the yellow plastic wheels to the black plastic tires — it's just a tight fit. You may be able to push the wheels out with your bare hands. If not, just place the tire facedown over the center of a roll of masking tape, and tap the axle hole lightly with a hammer. The wheel should loosen and pop right out.

2c. Remove the metal cab deck. With the wheels removed, turn the chassis upside down. Inside the front wheel wells, you'll see 4 bent metal tabs that hold the metal cab deck to the plastic chassis. It may take some wiggling, but these tabs can be bent straight if you use a long flathead screwdriver (Figure C). Once the tabs are straightened and unbent, the cab assembly lifts right off the chassis Remove the plastic windshield and the rubber exhaust pipe, and put them in a safe place for later.

2d. Remove the dump bed from the chassis. This is the only tricky part of the deconstruction process. The dump bed is attached to the chassis with 2 metal rivets. These must be drilled out. Begin by using a small drill bit to create pilot holes in the center of each rivet (Figure D).

Using the pilot holes as a guide, swap in a 7⁄32" drill bit to bore out the rivet entirely. Be careful! Although the metal is tough, the plastic chassis is soft, so avoid drilling the holes in the chassis beyond their original size. It's not the end of the world if the holes get a bit frayed, but try to minimize the damage to the plastic as best you can.

2e. Remove the Tonka stickers. The decals that come attached to the Tonka may not match your planned design, so you probably want to remove them. The stripes on the sides of the dump body are simple enough to scrape off, and you can remove any adhesive residue with Goo Gone. Be gentle when peeling the decals from the sides of the cab. If you remove them in one piece, they can be reused as handy templates for making replacement decals that match your paint scheme.

When you're finished, you should have a collection of parts that looks like Figure E.

3. Prep for painting.

Out of the box, Tonkas come with glossy yellow paint. Stripping the gloss from the metal surfaces will help your new paint adhere. Use very fine grit sandpaper or, even better, a finishing sander wheel to get rid of the shine (Figure F). When you're done, the old paint should be an even, dull yellow.

4. Bring the color.

Once your Tonka is prepped, you can paint it. The truck body can be painted one color, and the wheels painted as a contrasting accent. On the chassis, the grill and gas tanks can be masked and painted silver to give them a chrome look. Just think of the Tonka as a canvas, and paint it accordingly.

Regular Krylon spray paints work fine; just be sure to apply the paint in even strokes and allow plenty of drying time between each coat. Lay on several coats to create a hearty finish. Automotive finishes look better and are even more durable, if you have access to a proper painting booth (or if you can convince your local auto body shop to paint a Tonka for you). Whatever finish you'd apply to a real custom car or truck, you can also apply to a Tonka.

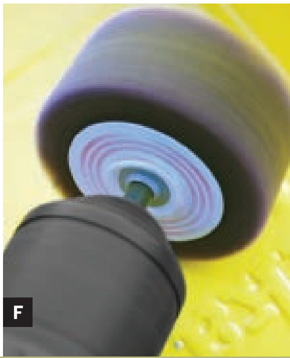


Fig. A: The Tonka Classics Dump Truck by Hasbro. Fig. B: Pry off the axle end caps to release the wheels. Fig. C: Use a screwdriver to bend back the tabs that hold the metal cab deck to the plastic chassis.

Fig. D: Drill pilot holes for drilling out the metal rivets that attach the dump bed to the chassis. Fig. E: Toy truck, fully disassembled. Fig. F: Sand down the original factory finish to rough it up for painting.

5. Rebuild it.

Putting a Tonka back together is even easier than taking it apart. Reinstall the exhaust pipe and cab windshield to the cab deck, then reattach the cab deck to the plastic chassis and secure it by bending the metal tabs inside the front wheel wells.

To reattach the dump body to the chassis, replace the original rivets with similar-sized machine screws, washers, and nuts. The screw heads go on the outside of the chassis rails, and the nuts go on the inside.

IMPORTANT: After you tighten the nuts, apply LocTite adhesive to secure the nuts in place. Without the LocTite, the nuts will wiggle loose when the dump body is repeatedly raised and lowered. If the nuts fall off entirely, they may become a choking hazard.

The wheels come next. Press the wheels back into the plastic tires. Thread each axle through one wheel, then the holes in the chassis, and finally the wheel on the other side. To reattach the end caps without chipping your freshly painted wheels, use two ⅜" sockets. Place one socket on your work surface and center one end cap inside it. Turn the truck sideways and insert the axle, then put the other end cap in a socket on the upward-facing wheel. Give the top socket a firm tap with a hammer. The sockets will spread the force around the end caps and lock them into place with no pressure on the wheels.

6. Add the flair.

With your Tonka repainted and reassembled, it's time to add accents and details. Contact paper or automotive decal sheets are good replacements for the Tonka stickers you peeled off. If you want a perfect match with the paint you used on the body of your truck, you can also spray a sheet of thin styrene plastic with your leftover paint. After the paint dries, cut the styrene to fit (using those old stickers as the template), then glue the trimmed pieces to the sides of the cab.

If you've got a steady hand and some artistic skill, you can pinstripe your truck or give it airbrushed graphics. If you lack either, laser-cut vinyl decals are an easy alternative, with hundreds of designs available, including popular cartoon characters, stripes, and flames. Look for them at your local sign shop or hot rod store, or on eBay. Happy motoring!

Todd Lappin is the founder of Telstar Logistics, a leading provider of integrated services via land, air, sea, and space.

HOMEBREW ALARM PURSE

Wire up a safety system with geek chic.

By Norene Leddy with Ed Bringas and Johana Moscoso

The Alarm Purse is a simple, fashionable way to add an audible alarm to your handbag. Tuck it away when you don't need it (so it won't go off by accident) and quickly hook it up when you do.

The latest addition to the ongoing Aphrodite Project (theaphroditeproject.tv/diy), the DIY Alarm Purse is part of a series of artworks and DIY projects that draw on the innovations of the courtesans of antiquity to improve the conditions of 21st-century women — empowering everyone with tools they can make to stay safe.

1. Make the alarm.

1a. Place the piezo siren inside the purse facing outward, allowing it to rest on the bottom. Measure the distance from the top of the siren to where the switch feels comfortable to hold. The top of the siren will be about 3" from the bottom of the purse.

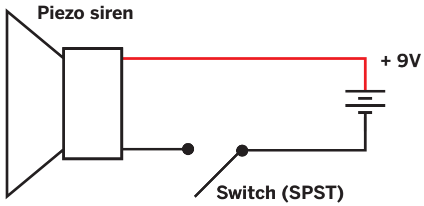
1b. Cut 2 lengths of 22-gauge wire long enough to connect the siren to the switch, and strip both ends of each wire (Figure A, page 116). Solder 2 ends to the terminals of the switch. If you're using a larger switch with holes in the terminals, thread the exposed wire ends through the holes in the metal switch terminals, then twist, as in Figure B.

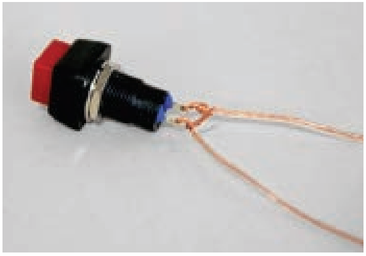
Cut two 1" pieces of heat-shrink tubing to cover the connections (Figure C). Slide the heat-shrink tubing up and shrink it around the terminals using a lighter or heat gun (Figure D). If you use a lighter, move the flame quickly back and forth; don't let it rest in any one spot. Once the tubing has shrunk and cooled, pull gently on the wires to make sure you have a secure connection.

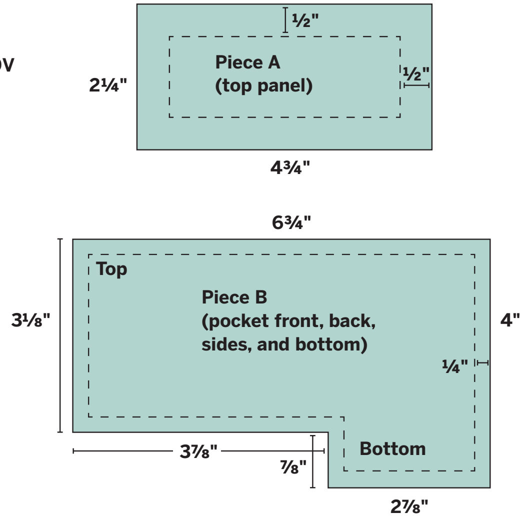
1c. Cut a strip of leather to cover the wire pair, from the switch to almost the ends, leaving about

Photography by Norene Leddy

Alarm Wiring Assembly and Pocket Pattern







MATERIALS

- **Purse**
- **Leather or vinyl scraps** to match or contrast with purse
- **Fabric scraps**
- **Velcro**
- **Barge cement** or other heavy-duty glue for leather
- **12V DC 102dB Piezo Siren audible alarm** RadioShack part #273-079 or similar from All Electronics (allelectronics.com)
- **9V battery**
- **9V snap connector** RadioShack #270-325 or similar
- **Push-on, push-off switch** All Electronics #PB-166, RadioShack #275-1565, or similar
- **1" heat-shrink tubing** RadioShack #278-1611 or similar
- **22-gauge wire**
- **Thread**

TOOLS

- **Leather punch**
- **X-Acto knife, Olfa knife**
- **Ruler**
- **Wire strippers**
- **Paper and pencil** for patterns
- **Lighter or heat gun**
- **Soldering iron, solder**
- **Sewing machine**
- **Chalk, tape, paper clip**

2" exposed. Make a paper pattern first to test the fit. The leather should be approximately 1¼" wide at the top to allow for the switch, and taper down to 1" at the bottom. Fold the leather in half lengthwise and sew it together, then slide the 22-gauge wires through using an unbent paper clip.

1d. Strip the wire ends of the snap connector and the siren, leaving ½" exposed. Attach the snap connector to the battery. Place a 1" length of heat-shrink tubing over the black wire from the siren, then twist this wire to the black wire from the snap connector. Fold the twisted pair back on itself, slide the heat-shrink tubing over the connection, then use a lighter or heat gun to shrink the tubing around the connection.

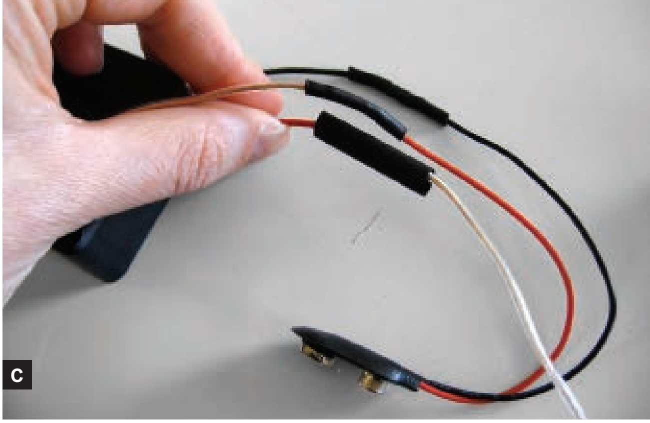
Using the same method, connect one of the switch wires to the red wire on the siren, and connect the other switch wire to the red wire on the snap connector. Use 2 short and 2 long pieces of heat-shrink tubing to cover as much of the exposed wire as possible. Test your alarm. It should be ear-piercingly loud.

2. Make the fabric pocket.

2a. Use the pattern diagram above and cut 2 pieces

A

B



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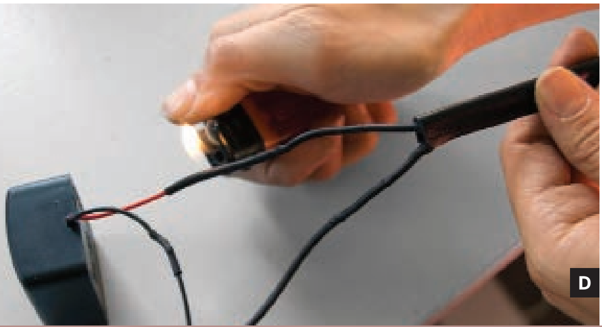


D

E

F

Fig. A: Strip the ends of the 2 strands of 22-gauge wire. Fig. B: If you're using a larger switch with holes in the terminals, twist the wire together. Fig. C: Cut 2 pieces of heat-shrink tubing to cover the connections.

Fig. D: If you're using a lighter to shrink the tubing around the terminals, move the flame quickly. Fig. E: Insert the alarm system into the pocket. Fig. F: The speaker holes on the outside.

of fabric to make the pocket: piece A for the top panel, and piece B for the pocket front, back, sides, and bottom. Add chalk lines for sewing. Sew the top fold of the pocket (B), then sew the bottom to the front, back, and sides of the pocket (B). Be sure to line up the chalk guidelines.

Next, sew 3 sides (2 long, 1 short) of the top panel (A). Fold over the edges twice for a nice, finished look. Fold the unsewn side of the top panel, and sew it to the side of the pocket. Use the pocket seam to line up the top panel.

2b. Cut 3 pieces of velcro: 1 approximately ⅝"×⅞", 2 approximately 1"×⅝". The 1" pieces will go on the front of the pocket, and the ⅞" piece will go on the side to secure the top panel to the pocket.

2c. Insert the alarm system into the pocket (Figure E). Attach the velcro around the speaker (don't block it) and to the top panel.

3. Attach the pocket.

3a. Make a pattern first, then cut a patch out of matching/contrasting leather or vinyl, slightly larger than the siren speaker, with small holes to let the sound of the alarm out. If you're using a leather punch to make the holes, tape the pattern to the leather first to ensure that they line up.

3b. Place the siren back in the pocket and insert it into the purse. Line up the pattern on the outside of the bag with the siren on the inside. Cut a hole in the bag slightly smaller than the pattern, to allow enough room to glue the patch along the edges.

3c. Attach the velcro to the inside of the purse, lining up the siren speaker with the hole. If the velcro comes loose when you remove the pouch, you may want to sew the corners into the lining or glue it with heavy-duty adhesive.

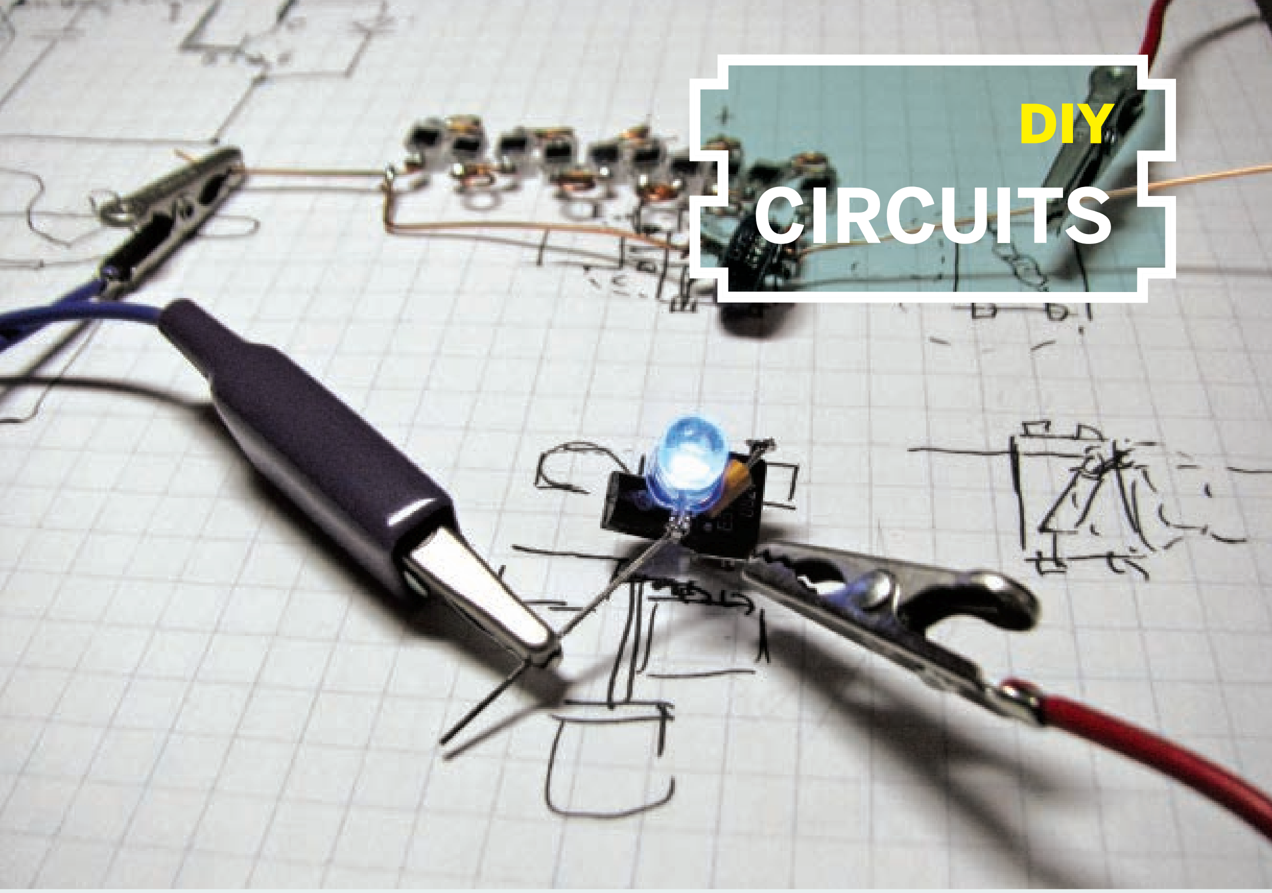
Glue the leather patch over the hole with shoe glue or other heavy-duty cement (Figure F).

4. Try out your alarm setup!

As the battery wears down, the alarm will get quieter, so be sure to test it before you go out.

+ A PDF of the pocket pattern and wiring schematic are online at makezine.com/19/diyspy_purse.

Learn about the Aphrodite Project at theaphroditeproject.tv/diy.
See more of Norene Leddy's work at nobetty.net.



"SOLAR JOULE" BRACELET

Solar-cell links are cleverly boosted to drive an LED jewel. By Edwin Wise

My wife fell in love with Alice Planas and Hatti Lim's glowing bracelet project from CRAFT magazne (*Volume 06, page 123, "Solar Jewelry"*), so of course we had to make one. I built the circuit and she did the fabric. It came out nicely, but I felt it could be improved, so I decided to combine the solar jewelry idea with a Joule Thief circuit that would make the LED glow brighter. The result is the Solar Joule!

Joule Thief Theory

The Joule Thief is a small circuit that converts low voltages, like from dead batteries, into an oscillating voltage with peaks high enough to be useful. There are many versions online (see makezine.com/19/diycircuits_solarjoule).

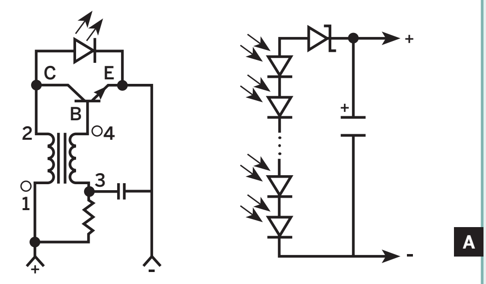
The heart of the circuit is a pair of inductor coils wound together into a transformer or choke. When current runs into one coil, it's resisted as it builds up a magnetic field. This field pushes current through the other coil, going in the opposite direction. In the Joule Thief, one coil provides the kick of voltage to light up the LED, and the other generates feedback that drives a transistor into oscillations.

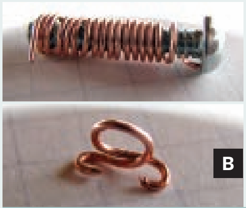
Here's how the feedback works (Figure A, left side, following page). When you first connect power to the circuit, the transistor is off, there is no magnetic field in the choke, and there's not enough power to turn on the LED. Some power leaks through the resistor into the transistor's base, turning it on a little bit. This lets a bit of current run backward through inductor coil 1-2 of the choke, creating an expanding magnetic field. As a result, current is run through inductor 4-3, which turns the transistor on even more. This positive feedback loop continues until the transistor is completely activated.

Once the transistor is done opening, the current

Photography by Edwin Wise

JOULE THIEF AND SOLAR BATTERY SCHEMATICS





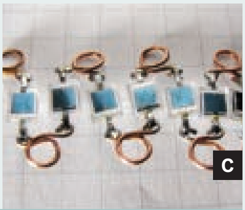


Fig. A: Dots indicate like-voltages on the choke. Fig. B: Loops of solid wire wound around bolt, cut, and bent. Fig. C: Photodiodes soldered in series, connected by wire loops.

MATERIALS

All values are approximate and not particularly critical

For the solar collector:

- **Wire, 22-gauge solid** **I used insulated wire and stripped the insulation.**
- **PIN photodiodes (10 or more)** **Mouser Electronics part #782-BPW34, mouser.com**
- **Supercapacitor, 0.22F** **Mouser part #598-EDLSD224V5R5C**
- **Schottky signal diode** **Mouser #625-SB330-E3**
- **Nice fabric** **or other bracelet material for mounting**

For the Joule Thief circuit:

- **Common-mode choke, 51μH** **Mouser #875-CC2824E513R-10**
- **NPN transistor** **Mouser #512-BC549**
- **Resistor, 1kΩ to 3kΩ, 1W** **such as Mouser #299-1K/AP-RC**
- **Capacitor, 0.01μF axial** **Mouser #80-C114C103K5R**
- **LED, any size or type** **such as Mouser #604-WP7113QBC/D**

TOOLS

- **Wire cutters**
- **Small bolt**
- **Small pliers** **Round-tipped are nice, for making loops.**
- **Soldering iron and solder**
- **Liquid flux (optional)**
- **Third-hand vise (optional)**
- **Voltmeter and/or oscilloscope (optional)**

through 1-2 stops increasing, so the magnetic field stops expanding and stops pushing the current through 4-3. This causes the transistor to close a bit, which reverses the feedback loop. Current reverses through 4-3, closing the transistor more and blocking current flow through 1-2. When the transistor shuts off, the inductor's magnetic field winds down and unloads a blob of charge, which then runs through the LED to light it. The current is quickly exhausted, and we are once again at the starting state.

The capacitor between the resistor and the choke provides a little "spring" to the feedback action, buffering some of the voltage changes across inductor 4-3.

Build the Solar Battery

First I built the solar battery, which is a series of PIN diodes bridged by a supercapacitor that stores the energy they collect (Figure A, right side). The photodiodes also act as links in a chain bracelet, and I connected them with loops of wire to provide some spring and make it easy to sew them onto fabric.

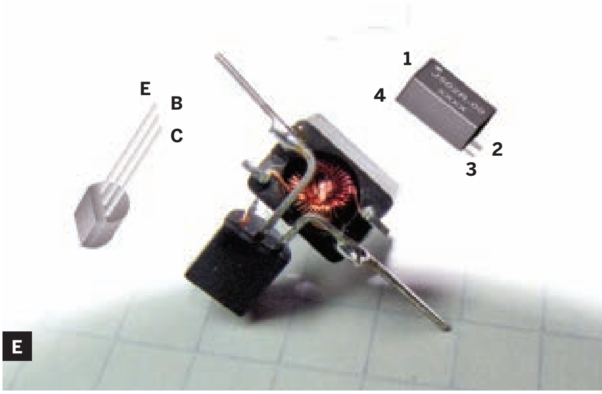
To make the loops, wind solid wire around a small bolt, cut it at every other turn, and re-bend the ends of each loop into small solderable hooks (Figure B). Then solder 10 (or more) diodes in series, + to – (Figure C). The silver strip on each diode's face indicates the + side. If you want to go crazy, make 2 strips of photodiodes and connect them in parallel, side by side (+ to + and – to –).

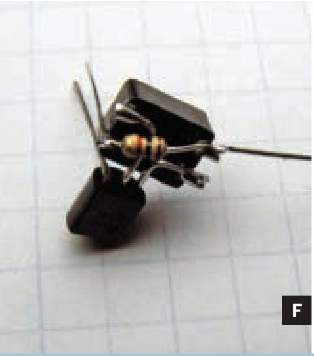
Solder the Schottky diode to the + end of the series, with its black stripe (the – end) pointing away from the photodiodes. The Schottky diode ensures that power flows into the capacitor when the photodiodes are in bright light, but won't flow back out when they're dark. Any diode will work here, but a Schottky diode consumes less voltage in the forward direction, saving more for the LED.

Solder in the supercapacitor, with its + side at the signal diode and its – side all the way at the other end of the PIN diodes. Finally, solder a wire to each end of the capacitor (Figure D), to connect to the Joule Thief later, and set the solar battery in the sun.

Build the Joule Thief

Many versions of this project involve winding your own transformer, but I'm lazy, so I bought one. It's a surface-mount (thus, very small) common-mode choke with a ferrite core. The white dot on top indicates pin 1, and the pins are numbered clockwise.





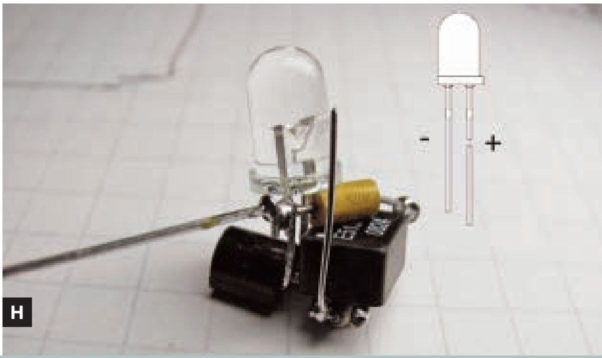


Fig. D: Solar battery with the Schottky diode and supercap soldered in. Fig. E: Solder the transistor collector (C) and base (B) to pins 2 and 4 of the transformer. Fig. F: Solder the resistor between pins 1 and 3 of the transformer. Fig. G: Solder the capacitor between the transistor emitter (E) and pin 3 of the transformer. Fig. H: Solder the LED "jewel" between the transistor's collector and its emitter.

Start by bending the emitter pin on the NPN transistor 90° away from the flat side. Then bend the collector and base pins so that you can solder them to pins 2 and 4 of the choke, respectively (Figure E). (Note where pins 1 and 4 go when you turn the choke upside down.)

Position the resistor across the base pin, bend its leads down the sides of the choke, and solder it between pins 1 and 3. Trim the pin 3 lead, but leave the pin 1 lead long to connect to the battery's positive (+) terminal (Figure F). Any resistor from 1K to 3K should work. A larger one will be more efficient, but I happened to have a 1K resistor on hand.

Flip the assembly over and solder the axial capacitor between pin 3 (or the resistor lead connected to it) and the transistor's emitter pin (Figure G). This capacitor isn't required for the circuit to work, but it increases efficiency. An axial capacitor fits better here than a regular disc-shaped cap would, so it makes the circuit more compact.

Now let's set the LED jewel. Bend out the LED's shorter cathode lead (–). Solder the anode lead (+) to the choke's pin 2 or transistor's collector. Solder the cathode to the transistor's emitter, which should be conveniently poking up. Trim the LED's anode but leave the cathode lead long (Figure H).

Solar Jewel + Joule Thief

Using wires or alligator clips, wire the Joule Thief and the solar battery together, + to + and – to –. The LED should glow! If you watch the LED's positive lead with an oscilloscope, you should see it pulsing up to the LED's forward voltage at 300kHz to 500kHz. Since that's too fast for your eyes to discern, it looks like a steady glow.

If it doesn't light, use a voltmeter to confirm that your solar battery has a charge. It doesn't take much; half a volt is plenty. But it may require many minutes of bright sunshine to charge the cap the first time. If you have voltage but no glow, confirm that the diodes, capacitors, and the choke's inductors are all oriented correctly.

I'm ignoring the final part of the project here: a crafty mounting that you provide for the other 2 parts. That's up to your imagination.

+ See makezine.com/19/diycircuits_solarjoule for schematics and a link to the original Joule Thief circuit.

Edwin Wise (simreal.com) is a software engineer with 25 years' experience. He develops software during the day and explores the edges of mad science at night.

BURNOUT SOUNDS

Guitar effects from old compact fluorescent light bulbs. By Andrew Carrell

When compact fluorescent lamps (CFLs) burn out, don't throw them out! Carefully pry apart the base with a flathead screwdriver, and you'll find a tiny circuit board stuffed with useful components. Then you can recycle just the bulb (be careful not to break it). Removing the bulb is the first thing they do at the recycler's anyway.

I've opened up a few different brands, and the contents are all pretty much the same. A typical inventory includes 2 transistors, four 1N4005 diodes, assorted ceramic capacitors and resistors, a 10μF electrolytic capacitor, and a small coil transformer.

I don't bother salvaging the resistors, but I use the film caps, transistors, and diodes to make guitar effects boxes. Fuzzes, boosts, and buffers — oh my!

Here are some CFL-based effects that I've concocted and had fun with. You can find the schematic diagrams at makezine.com/19/diycircuits_cflreuse, along with links to other CFL component projects and DIY guitar effects resources.

» **Fluorescent Fuzz** and **Shining Sixties Fuzz** These impart a 60s or 70s rock/psychedelic sound.

» **13 Watt Overdrive** This adds some 70s rock "crunch" to your tone.

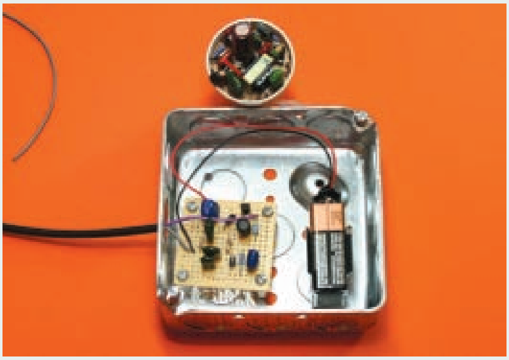
» **Light Ranger** This treble booster is great for making your guitar solos stand out and cut through the mix.

» **Bulb Booster** This makes your signal louder, pushes your amp harder, and generally makes everything sound better.

The schematics online show the core circuits. For a volume control, add a potentiometer between the circuit's output and the output jack on the box, with the third contact going to ground. Using a stereo jack for input lets you either activate the effect circuit or bypass it, depending on whether the 3PDT step switch connects to the right or left channel.

For all of these, you solder the circuits onto a small piece of perf board, then add leads to connect out to the battery snap and input/output jacks. To secure the circuit board inside the box, I use velcro tape.

For inspiration and help with my various DIY audio projects, I give credit to diystompboxes.com, muzique.com, buildyourownclone.com/board, and geofex.com. They all host great communities with great people.



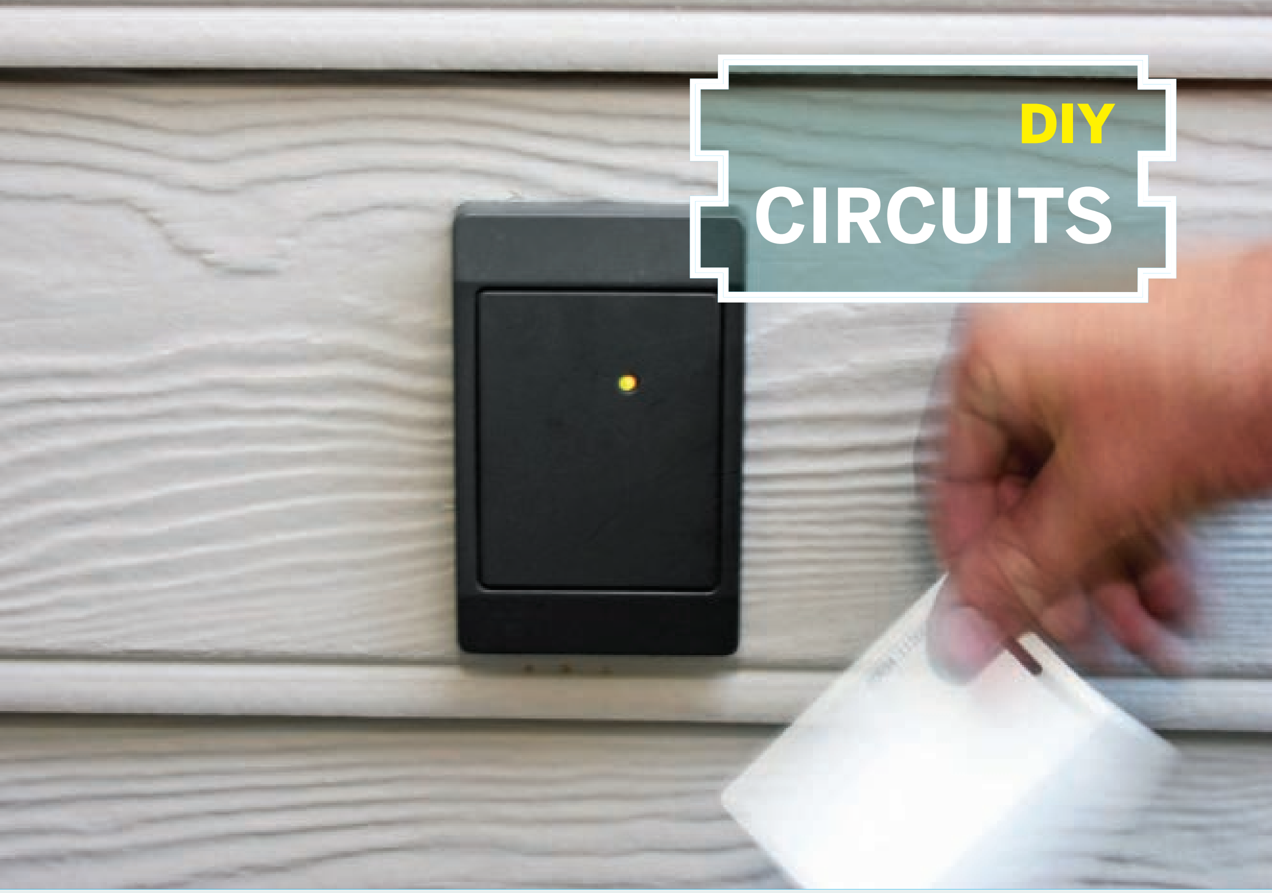
Photograph by Ed Troxell

MATERIALS AND TOOLS

- **Old CFL bulb**
- **Resistors** Values vary for different effects; see schematics online at makezine.com/19/diycircuits_cflreuse.
- **Potentiometer, 100kΩ**
- **Small perf board**
- **Hookup wire**
- **¼" audio jacks, 1 stereo and 1 mono**
- **3PDT (triple pole, double throw) step switch** available from Pedal Parts Plus (pedalpartsplus.com), Small Bear Electronics (smallbearelec.com), or diystompboxes.com. You can also use a DPDT (double pole, double throw) switch, but that's suboptimal.
- **Case** available from Pedal Parts Plus or Small Bear Electronics. Or you can use any small, strong box (like a circuit junction box), or make your own.
- **Velcro tape**
- **Flathead screwdriver**
- **Soldering materials**

+ Visit makezine.com/19/diycircuits_cflreuse for schematics, resources, and links to more CFL component projects.

Andrew Carrell caught the electronics bug from his Dad and currently makes music (and sometimes noise) in Austin, Texas.



BREAKING AND ENTERING

Open and repair a damaged proximity swipe card. By Graham Cattley

It all started one day at work. I had used my swipe card to get through the front doors, and without thinking too much, I put it in my back pocket. Later that day I sat down — crunch! The card had cracked from side to side. I wrapped it in tape to hold it together, and it still worked for two weeks, but then something in it failed. I tailgated people in and out of the building that day.

I had paid my company a $100 deposit on that pass card, and that night I decided I wasn't going to give it up by asking HR for a new one. I was determined to fix it myself.

A bit of research showed that these pass cards are often called "proximity cards," and operate in a manner similar to the tiny RFID tags found inside the new U.S. passports and even pet dogs. (See "How Does It Work?" on the following page for a basic explanation of their operation.)

Bending the card slightly to widen the crack revealed a coil of fine copper wire inside, and when I dismantled the card completely, I was surprised to find that its plastic shell contained not only a coil but also a small integrated circuit (IC) on a printed circuit board (PCB). Even more surprisingly, it had no battery!

I carefully removed some of the outside shell to reveal more (Figure A, following page), and then exposed the coil and PCB completely.

With the aid of a jeweler's loupe, I could see that the wire coil had broken —in many places, unfortunately. It would have been a major job just to identify the correct wires to solder back together, let alone actually doing it! Plan B was to wind my own coil, but back in the depths of my mind were the makings of Plan C: replacing the coil with one from another card.

Photography by Ed Troxell

After 20 minutes pawing through one of my junk boxes in the attic, I found an old pass card from a previous employer. It carried a different code, so it wouldn't work at my current office, but its coil was intact. What's more, the heat in the attic had dried out the glue — the card practically fell apart in my hands (Figure B). Plan C was the way to go!

I used a sharp craft knife to pry away the old glue that held the coil and mini PCB to the plastic shell. I took great care, as I couldn't afford any breakages. After 10 minutes, the salvaged coil was free.

I unsoldered the donor coil from its original PCB using a fine-tipped soldering iron, holding the PCB with a pair of locking tweezers. This was easy, as I didn't have to worry about overheating and possibly damaging the old IC. After removing the coil, I tested its continuity with a multimeter. Success! The coil was intact.

The tricky part was attaching the new PCB. This time, I had to be careful to keep the iron on the joint for as little time as possible, since the PCB was small and could quickly overheat, killing it forever.

Things went well, though, and because the ends of the coil were already tinned where I removed them from the old board, the joints were easy to make. The coil from my old card was now connected to the mini PCB from my new card.

Now it was time to look at the housing. My old card's shell was filled with dried-out glue and covered with ground-in grime. Fifteen minutes later the case was clean, thanks to some isopropyl alcohol, a soft cotton rag, and a bit of elbow grease.

The last step was to position the coil and PCB in the old case and hold it in place with a few drops of glue (Figure C). The card's thin plastic backing had suffered from the cleaning process, so I elected to replace it with a piece of clear, self-adhesive book film trimmed in place with a craft knife. (White book film would have been fine, but with clear film, the card made a great talking point with my co-workers.) The results looked good, but the acid test would have to wait until the next morning at work.

At 8:36 a.m. I waltzed up to the front door and waved my pass at the security panel. "Click!" went the door. "Woo hoo!" I shouted. The guys in HR couldn't understand why I was smiling so much that day.

Graham Cattley has been obsessed by electronics since he was 4, and has published numerous technical electronics articles in Australia over the past 15 years.

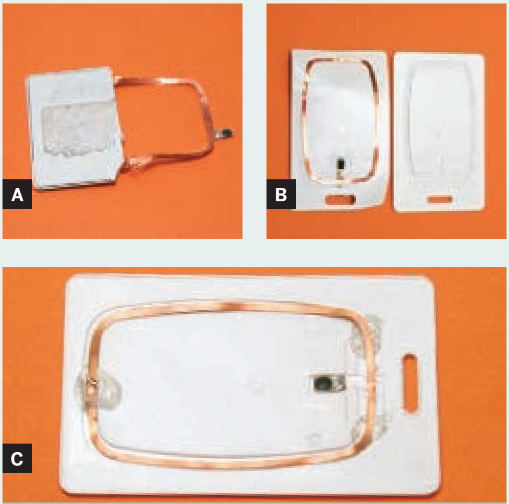


Fig. A: Removing part of the shell reveals the tiny circuit board and damaged coil. Fig. B: The old, donor card. Its coil is intact, but its chip contains the wrong code. Fig. C: The good chip soldered to the donor coil, in its case.

RFID Tag: How Does It Work?

There's a lot of misinformation out there about how RFID works. Here's a typical explanation:

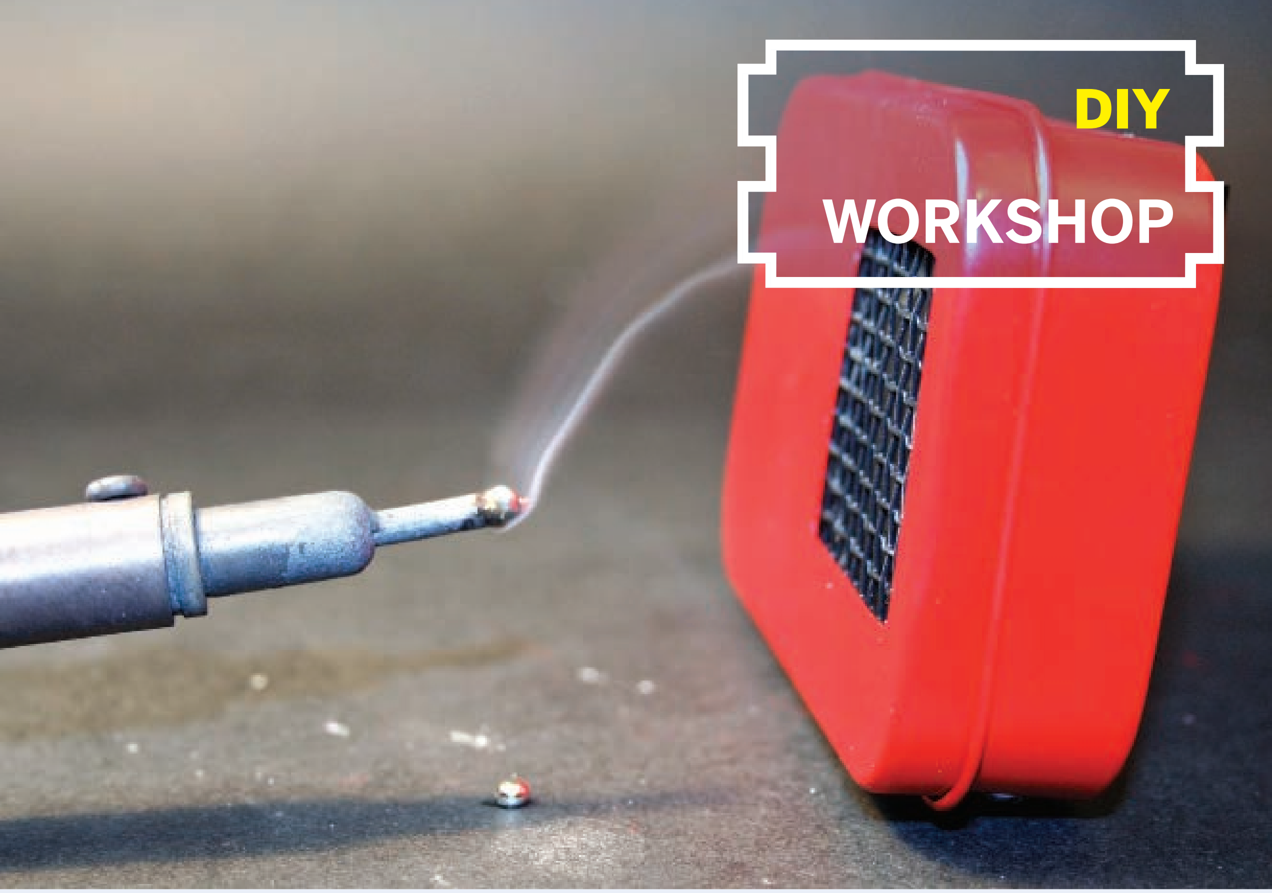
The reading unit (attached to the door) transmits radio energy. The card receives this energy, converts it to electrical energy, and then uses it to transmit its serial number back to the reading unit, which recognizes the card and opens the door.

While this is neat and simple, it's also wrong. Yes, the card's coil antenna absorbs the RF energy, and this is used to power the chip, but technically speaking, the card doesn't transmit anything at all!

Without going into the gory details (look up "load modulation" if you want them), you can better explain RFID with the following analogy:

Let's say you're out on a boat, and you want to use a mirror to send information to a lighthouse. You can encode it in a binary format and then transmit one bit each time the lighthouse beam sweeps by, where reflect means 1 and not reflect means 0.

Security pass cards use the same principle, but instead of one sweep every 10 seconds or so, the reader transmits at 125kHz. The card's chip communicates its data by selectively shorting out its coil over successive cycles of the 125kHz transmission. A shorted coil doesn't absorb any of the RF energy, while a non-shorted coil does, so the reader then distinguishes 1 from 0 by measuring the peak voltage on its antenna to see if it's high or low. In this way, the card communicates its 24-bit serial number, along with synchronizing and checksum data.



MINI FUME EXTRACTOR

Candy tin device helps keep your air clean and your lungs healthy. By Marc de Vinck

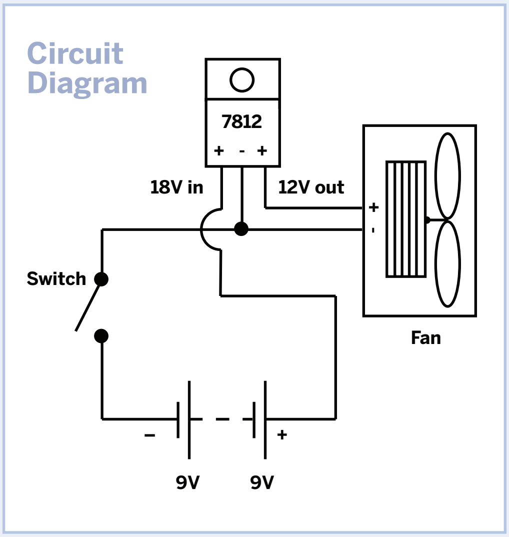
A fume extractor uses an activated carbon filter and fan to remove the smoke, and noxious fumes, created from soldering. The average price of a small hobby version is about $100, but this one will run you more like $10. This mini fume extractor won't be as effective as a larger one, but it's definitely better than nothing, and extremely portable. Remember, always work in a well-ventilated area.

1. Build the circuit.

I decided a quick mock-up might be a good idea, and I'm glad I did. At first, I thought that running the case fan off just one 9-volt battery would provide adequate power. In the end I decided that 12 volts "sucked" better, and in this case that's a good thing.

The final circuit (at right) uses a simple switch, two 9-volt batteries, a 40mm case fan, and a 7812 voltage regulator. The 7812 takes voltage from the

Photography by Marc de Vinck



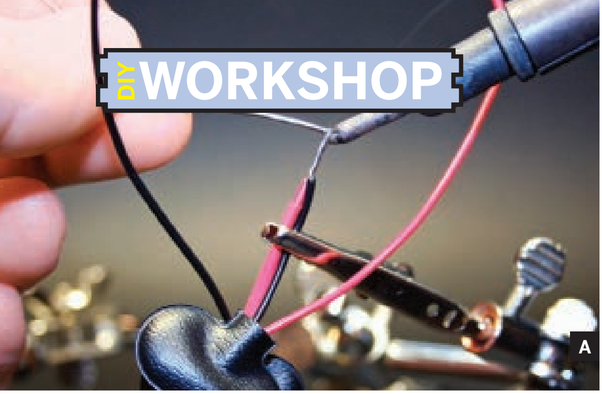


Fig. A: Vinyl 9-volt connectors are low-profile enough to let everything fit. Fig. B: The completed circuit. Make sure to orient the 7812 according to the schematic, and don't forget to slip on heat-shrink tubing prior to soldering, to insulate all connections from the conductive metal tin. Fig. C: It's a snug fit. Fig. D: Use light pressure when cutting the openings; let the tool do the work. The openings don't have to be perfectly aligned.

MATERIALS

7812 voltage regulator IC
Candy tin
Switch, SPST (single pole, single throw)
Case fan, 40mm square
9-volt batteries (2)
9V battery connectors (2) vinyl, not hard plastic
Pieces of screen, 50mm square (2)
Piece of carbon filter cut from a replacement filter
Heat-shrink tubing
Insulated, threaded hook-up wire
Miscellaneous screws and washers
Paint (optional)

TOOLS

Soldering iron
Rosin-core solder
Dremel with cutoff wheel
Drill and small drill bits
Fine-tip marker
Various screwdrivers
Wire cutters
Safety glasses

CAUTION: Wear safety glasses when drilling and cutting metal!

9V batteries wired in series and steps the voltage down from 18V to 12V, which is what the fan requires.

2. Solder the components.

Notice the battery connectors (Figure A); they're the flexible vinyl version, not the hard plastic type. This allows both batteries to fit in the case. The vinyl snaps are only minimally smaller, but it's enough to make the difference.

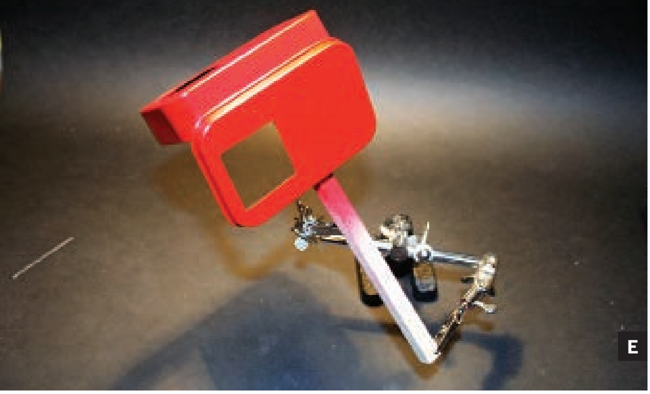
This is a very simple circuit. Solder it according to the diagram, making sure to attach the component leads to the 7812 properly (Figure B). Don't forget to use heat-shrink tubing on all connections; this is in a metal box ... and metal conducts electricity!

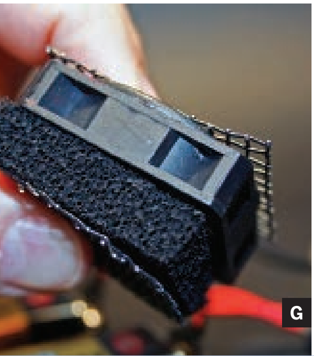
3. Make sure it all fits.

It's a snug fit, but you should be able to stuff everything into the tin, packing the batteries side by side next to the fan (Figure C).

4. Cut and drill the holes.

I used a marker and a paper template for the fan openings, making them 35mm square on each side. After you cut the first fan hole, close the box and use the template to align the second hole. You can just "eyeball" the placement. There's room for error.





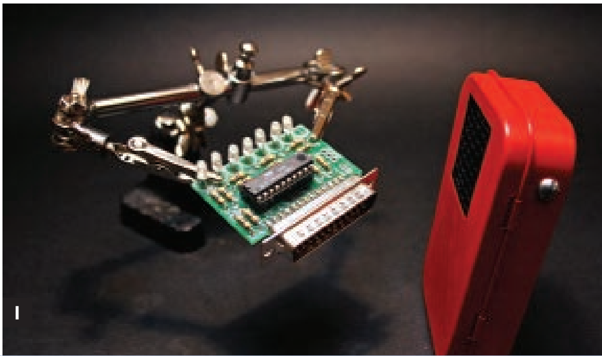


Fig. E: Mount the tin to a wooden stick with hot glue. It can easily be removed, and your hands won't get all red! Fig. F: Attach the 7812 and the switch with a few screws. Fig. G: Screen, filter, fan, and screen make a nice little sandwich. Fig. H: All ready for your next soldering project. Fig. I: It works great, it's highly portable, and your lungs will thank you.

Then I marked the opening for the switch and cut all openings with a Dremel tool and cutoff wheel (Figure D).

Next I marked and drilled 2 mounting holes for the switch screws and one for the regulator.

5. Paint and decorate.

I decided to paint the tin this time, unlike my plain RuntyBoost (makezine.com/go/runtyboost). I chose a nice red Krylon paint. I hot-glued a scrap piece of wood to the inside, so I could hold it while I spray-painted it. Two quick coats and I think it looks good (Figure E). Spray paint can be fairly toxic and flammable, so paint outside and away from everything! I'm happy with how it came out, but it definitely needs some graphics to spruce it up. Any suggestions?

6. Attach the regulator and switch.

First, screw in the 7812 using some washers and a screw to space it slightly away from the side of the tin (Figure F). I used a #6-32 screw and one washer to keep it from the edge, but you can use anything that fits. The screws and washer will also act as a heat sink.

Finally, screw in the switch.

7. Add the screens and filter.

Here you can see the screen-filter-fan-screen sandwich (Figure G). The screens are 50mm square and the filter is 40mm square. You can buy replacement filters for the commercial extractors at a reasonable price and cut them to size.

Next, just hot-glue or epoxy the corners of the screens to the candy tin, and sandwich the filter and fan in between (Figure H). Compression will ultimately hold it all together. You're done!

8. Test your extractor.

I've run mine continuously for hours and have had no heat buildup from the 7812, and the fan is still running strong (Figure I). It works quite well, and although it's no replacement for a large fume extractor, it will come in handy for small projects. Remember, follow all safety guidelines when soldering, and work in a well-ventilated room, even if you have a fume extractor.

Marc de Vinck is a member of the MAKE Technical Advisory Board and a writer on makezine.com.

DIY DRAWER ORGANIZER

Got commercial organizers that fail to fit? Make your own. By Conrad Hopkins

Store-bought drawer organizers hardly ever fit my drawers. They're not the same size as my drawers, nor are they as deep. So, they don't actually organize all that well.

But it's possible to make a custom drawer organizer for any drawer in your kitchen, workshop, or desk. Here's how to do it easily and inexpensively.

MATERIALS

⅛" acrylic sheet (plexiglass) or other material to use as the body, such as wood
Glue and applicator I used TAP Acrylic Cement (tapplastics.com). You could also use Weld-On #3 or #4.
Weights I used some metal bars, but canned food, small free weights, or even a container filled with sand or water would work.

TOOLS

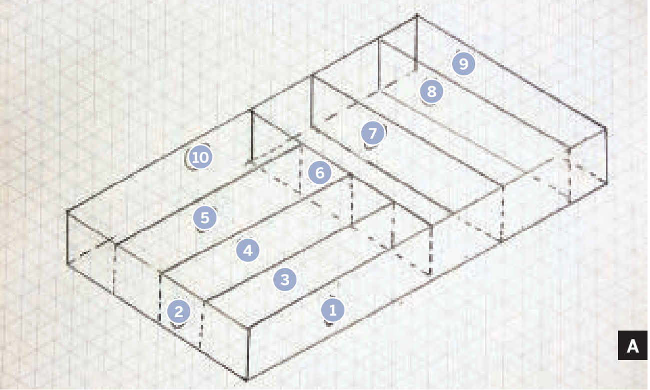
Ruler
Paper and pencil
MAPP gas torch or propane torch (optional)

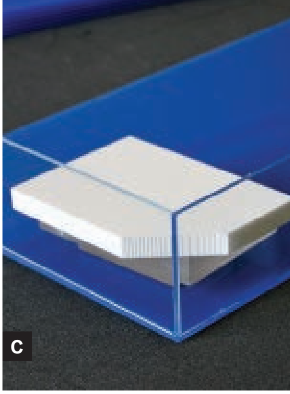
1. Measure the height, width, and depth of your drawer. My drawer is 19¾" long, 10¼" wide, and 2¾" deep.

Then draw a picture and decide how you want to divide it up (Figure A). Now measure each compartment, taking into account the thickness of the material being used as dividers.

2. Write up a materials list. I used ⅛" clear acrylic (plexiglass) because it looks clean and is washable (as opposed to wood). My measurements came out as follows. The 8 smaller pieces are for the 2 end pieces and 6 interior dividers.

Photography by Conrad Hopkins





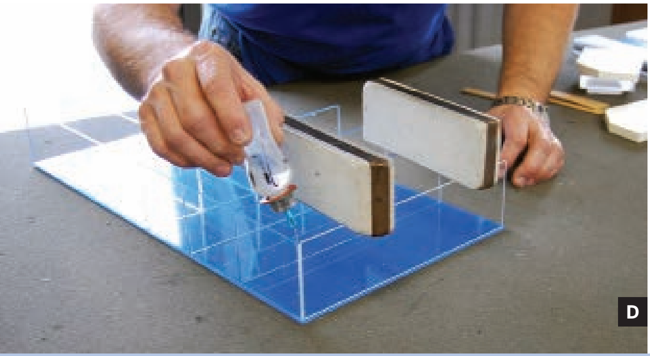


Fig. A: After measuring your drawer, draw your dream organizer and measure its parts. Label the pieces. Fig. B: This acrylic cement is applied with a needle applicator bottle. Fig. C: Prop the pieces with square scraps to maintain right angles. Fig. D: Weights help maintain good contact while the glue sets. Fig. E: For the finishing touch, break out the gas torch for a professional-looking flame polish!

Bottom 19¾"×10¼"
2 sides 19¾"×2⅝"
8 pieces 2⅝"×10"

NOTE: The drawer is 2¾" deep, but the sides and dividers are only 2⅝" deep because they'll rest on the ⅛"-thick bottom piece. The same math was used to determine the divider widths.

3. Obtain your plastic or other material. I got mine cut to size at a TAP Plastics store, so I didn't need any tools (you can also order from tapplastics.com). You'll also need glue and an applicator (Figure B).

4. Peel the masking off one face of the bottom piece, and off both faces of one of the long side pieces (19¾"×2⅝"). Place the side piece on the unmasked face of the bottom piece. To keep a right angle, I used a couple of pieces of plastic with a corner cut off so they wouldn't touch the glue joint (Figure C).

Gently squeeze the applicator bottle and drag the needle along the corner formed by the 2 pieces. Glue will flow into the joint and set in a few minutes.

5. Glue the pieces together in the order shown in Figure A. Peel the masking off one end piece and glue it in place (Figure D). Add the dividers, the other end piece, and finally the second side piece.

TIP: Weights will help maintain better contact between the pieces, to make stronger glue joints.

6. To give the divider a professional look, you can flame-polish the edges. A MAPP gas torch works best, but you can also do it with a propane torch. Quickly move the flame along the edges and watch them go from dull to polished (Figure E). Make sure you wait a couple of hours for the glue to fully dry first.

7. Give the glue at least 24 hours to build up strength. Remove the masking from the bottom, then put the divider in the drawer and enjoy!

There are some great free how-to videos at tapplastics.com with more ideas.

Special thanks to Jim Beddow at TAP Plastics in San Rafael, Calif., for his help and advice.

Conrad Hopkins is the director of human resources at TAP Plastics, where he also conducts product training.

JEWELED FINISH

Give your metalwork a gleaming texture that makes light dance. By Brian Dereu

Engine turning, or jeweling, is a striking, prism-like finish that's applied to metal surfaces. Traditionally used on pocketwatch cases and rifle bolts, it can be applied to tools, lighters, or any other area of metal.

And although it is labor intensive, it's not difficult to accomplish. All you need are a drill press, valve grinding compound (Clover brand or similar), and some miscellaneous items found in the shop.

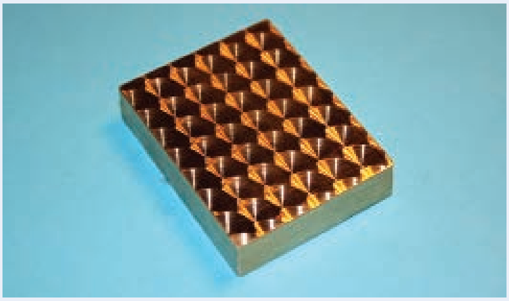
The pattern is accomplished by applying the abrasive, lowering a spinning tool onto the work for a few seconds, then raising it, moving the work piece over, and repeating until the entire surface is worked. A moveable, indexable table is ideal for this type of project, but you can produce results just as good by using a scale and a few spacers.

Although jeweling will hide surface imperfections, it's best to start with a nice finish. Here's how to give a mirror finish to softer nonferrous metals like copper, brass, and aluminum.

As in woodworking, work through progressively finer grits of sandpaper, up to 600. After using 600 grit, you can see reflections in the metal, though they will be foggy. Rub a small amount of metal polishing compound on the backside of a sheet of sandpaper, and then run the metal surface across it, back and forth. Soon a mirror-polished finish will jump out and the metal is ready to jewel.

To apply the pattern, use a short piece of wooden dowel, about 3" long and 5⁄16"–3⁄8" in diameter. Chuck up the dowel in a drill press. Set up the drill press table so that your work piece can slide along next to a scale that's been fixed to the table. Super glue works well for this, and can be scraped off later. Set the drill press to around 1,000rpm and apply a good amount of grinding compound to the work. A medium-grit (200 to 300) compound works well.

Start by lowering the dowel in the far corner, and apply 3lbs–5lbs of pressure for 3–5 seconds. Raise the dowel, move the work the desired distance, and continue, until the first row is complete. It's important to maintain the same spacing throughout the entire surface, in both the x and y axes. The dowel should be changed intermittently to prevent it from mushrooming out at the work end, which will increase the size of the burnish.



Photograph by Brian Dereu

After the first row is complete, add a spacer between the work and the scale that's the same thickness as the distance between each burnish. Graph paper can also be used as a spacing grid. The sample shown above has spacings of 1⁄4" in both the x and y axes.

Small circular wire brushes are also used instead of dowels, usually on harder metals like carbon steel and stainless steel. Bridle the brush by wrapping its wires with a few turns of electrical tape down most of its length, to keep it from flaring. There are also round, rubberized abrasive sticks (such as Cratex brand) that can be used as jeweling tools. Cratex sticks don't require the use of grinding compound, but they're not very aggressive, and can be used only on a super-polished surface.

After the entire surface has been finished, gently rinse away the remaining grinding compound. Some of the compounds are oil soluble, and must be rinsed away with paint thinner, acetone, or a similar solvent. Don't rub off the compound with a rag, or it will scratch. When all the compound is rinsed off, wash the work piece in soap and water, and dry it.

Most metals will oxidize over time. To keep the surface looking new, protect it with a clear coat, such as a spray lacquer. Don't delay on this step, as visible oxidation can take place in a very short time.

Brian Dereu is a self-employed manufacturer who enjoys gadgets, fishing, and family.

MIDI CAMERA CONTROL

ESPN-style coverage with a video crew of one or two. By Josh Cardenas

I had the chance to run visuals for a unique DJ act called The Hard Sell, a collaboration of turntablists DJ Shadow and Cut Chemist. The art of spinning and cutting records is usually not visible to dance club audiences. Cut and Shadow wanted to let everyone see, up close and personal, all the action on their 8 simultaneously spinning turntables playing old 45s.

But they needed a way to do it unobtrusively. Given the often cramped spaces of the venues they perform in, they couldn't have a crew of sweaty dudes in black clothes wielding cameras in their faces. Also, Cut and Shadow wanted to mix in additional visuals from DVDs, to change and match the moods of the different tracks.

I got involved when Ben Stokes, the show's lead visualist, said to me: "I like robots. I like cameras. I *love* robot-cameras! You build all kinds of crazy stuff; what can you come up with for this?"

I suggested I could probably make some small robotic mounts for the cameras, each with their own pan-and-tilt mechanism driven by hobby servos. They'd be small, light, cheap and effective — my favorite combo!

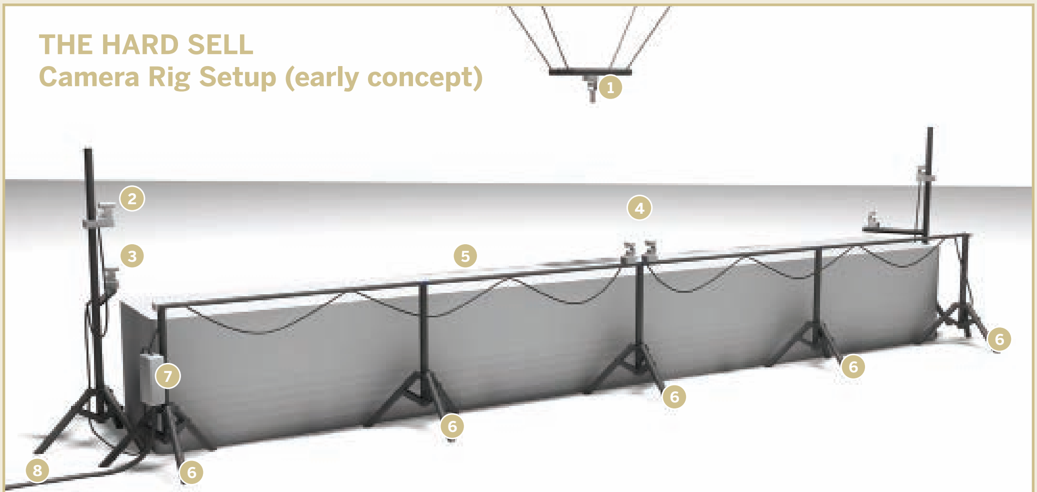
Here's the multi-camera live setup I devised for the show, and a lower-budget version that you can put together without all the professional equipment.

Cameras and Servos

For cameras, we used standard CCD security cameras with composite video output (camcorders would have been too large and heavy). For the mounts, I found a nice little prefab pan-and-tilt bracket from servocity.com that worked with hobby servomotors. A handful of these brackets and a pair of servos for each one, and we had a bunch of quick and easy rigs, ready to be powered up.

Photography by Neal Skacel

THE HARD SELL
Camera Rig Setup (early concept)



1. Overhead cam
- » Roll and pan with overhead mounting
- » Support frame hung from lighting grid
- » Needs independent power supply
- » Wireless MIDI receiver

2. Pole climber cam
- » Pan and tilt
- » Additional motor for vertical pole climbing
- » Extra-long height extension

3. Rear/side cams (2)
- » Standard pan and tilt with pipe mounting
- » On movable extension beam for easy positioning

4. Track cam
- » Pan and tilt
- » Additional motor for horizontal track travel
- » 2 units could be slaved together, then split for split/stereo effect, or work independently

5. Track
- » 24'–32' long, per final DJ console length
- » Modular; breaks down into 3' or 6' pieces with solid metal connectors
- » Blocks for stopping carriage at each end

6. Tripod pipe stands
- » To support track and side poles
- » Number needed varies
- » If stands too obtrusive, mount track on console

7. Control breakout box
- » 8 composite video ins
- » 8 MIDI thru (powered)
- » 8 cam power outs
- » 1 "snake" cable with:
  - 8 composite video outs
  - 1 MIDI in (or WiMIDI uplink)
  - 1 control box power feed
  - 1 pipe mounting bracket

8. Control "snake"
- » Leads to control offstage
- » 50' max length if using wired MIDI

MIDI Control

We mused about having the cameras move autonomously in random patterns, but decided we wanted control over each, so we could frame the shots and follow the artists as they moved from deck to deck.

Hobby servos are built for R/C, of course, but the prospect of relying on a multichannel radio transmitter wherever we performed made me nervous. In a performance-critical environment, I didn't want interference from any wireless mics, radios, and other devices that happened to be operating nearby.

Instead, we kept things musical by using MIDI, which is the standard protocol for electronic music hardware and software. Since MIDI is multichannel, we could control many cameras from the same interface. And in addition to enabling live control, MIDI let us record, edit, and play back camera movements just like you can record, edit, and play back music.

To bridge the gap between our MIDI control signal and our pan-and-tilt hobby servos, we used the ServoCenter control board from Yost Engineering. This little circuit board has MIDI sockets and connectors for up to 16 standard hobby servos.

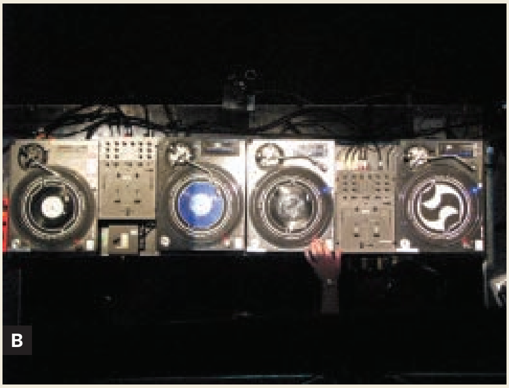
The ServoCenter translates MIDI's Continuous Controller (or CC) messages, which are usually associated with knobs or sliders, to corresponding servo control signals. By configuring which CC channels run which servomotors, you tie the controls on any MIDI device to the cameras.

For the Hard Sell tour, our MIDI controller was a Korg MicroKontrol, a 3-octave keyboard with a row of 8 knob-slider pairs over the keys. We assigned each knob-slider pair to a different camera, with the knob set to pan and the slider set to tilt.

Our camera setups (above) changed as the tour progressed, with the most ambitious being at the Hollywood Bowl: several cams on poles captured the DJs' setup, a couple cams on the floor took extreme

Illustration by Josh Cardenas


A


B

angles of the DJs (Figure A) and the crowd, an overhead camera looked down (Figure B), and a cam mounted on a robotic dolly I built ran back and forth on a track in front of the two DJs, allowing us to get some very dynamic, moving shots. The speed and direction of the dolly were controlled by MIDI as well, with the ServoCenter driving a beefier servo that turned the dolly's rubber wheels.

Mixing the Video

The next question was how to switch or mix the multiple video feeds for projection onto the big screen. With our 9-cam Hollywood Bowl setup we used a security camera DVR, which let us switch feeds and also record all the cameras — the entire show (albeit at low quality) — direct to a hard drive.

At other shows we used an Edirol V-4 video mixer, a favorite VJ workhorse that can switch, mix, and apply effects to 4 simultaneous video streams. The mixer let us intercut the cam feeds, morph them into more abstract patterns, and add in any DVD visuals we queued up.

As we did more shows, we devised new ways to bend the technology to our will. We tried recording the MIDI control messages with music software on a laptop, then playing them back as pre-orchestrated camera moves. Also, I had been experimenting with VVVV, a free software toolkit for prototyping multimedia applications. I wrote VVVV routines for my laptop that generated MIDI commands to move the cameras in patterns, such as sine waves.

After some more tinkering, I was able to bring camera video streams into my laptop, then manipulate or mix them with other graphics, all in VVVV. (You can do the same thing with other software as well, such as Pure Data, Max/MSP, and Quartz Composer.)

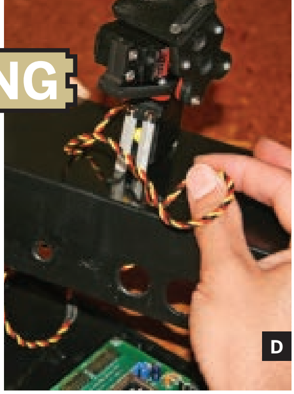
Try This at Home

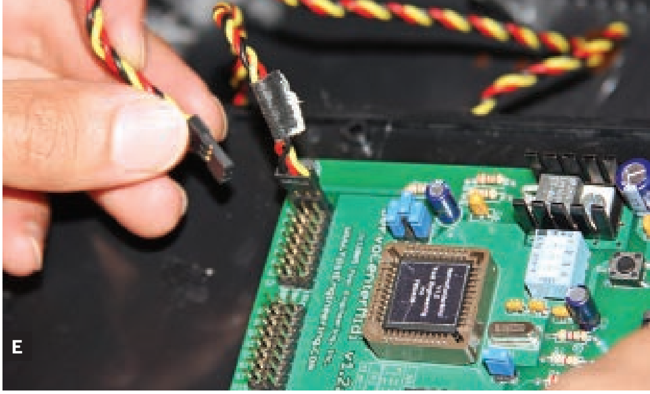
Working on the Hard Sell tour made us realize the possibilities of MIDI cams. With setups like this, just 1 or 2 people could provide dynamic, multi-camera video coverage for all kinds of live events: sports, performances, contests, demos, even pranks. Now I also wonder how many tiny robotic cameras I could manage at once.

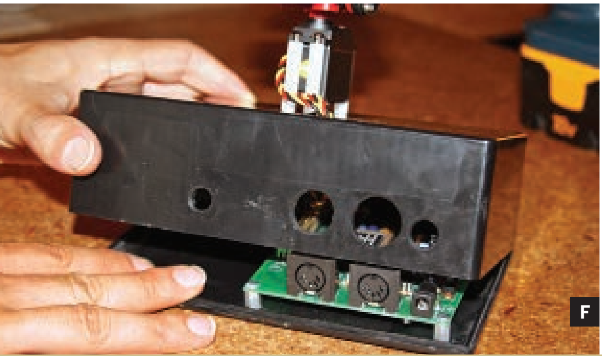
Running VVVV on a laptop, you can eliminate the need for the high-end hardware we used on the Hard Sell tour. I concocted a work-alike system that uses just a PC, the servos and ServoCenter, and a webcam for video capture. Computing power is a factor, but a fast computer can handle simple mixing with 2 video feeds. Just make sure the webcams are different brands, so that Windows won't see them as having identical IDs (I have heard that FireWire webcams don't have this problem).

MATERIALS AND TOOLS

USB webcam Most computers will be overwhelmed by video coming from more than 2–3 cameras.
Servomotors, standard hobby size (2 per camera) I used Hi-Tec model #HS-645MG.
Pan-and-tilt brackets to fit the servos. ServoCity part #SPT100 (makezine.com/go/brackets)
ServoCenter full package, MIDI $90, item #SCPMIDI from tech.yostengineering.com. This includes the controller board, AC adapter, MIDI cable, software, and documentation.
USB-MIDI interface I recommend the M-Audio Uno.
Windows XP-based PC VVVV doesn't run on Vista.
Project box, 4"×8"×2" Plastic is easiest to work with.
Standoffs with matching nuts: 1¼" (4) and ⅜" (4)
Electrical tape
Double-sided tape or velcro tape, or even zip ties
Phillips screwdriver, slip-joint pliers
Drill with ⅛"–⅝" step drill bit







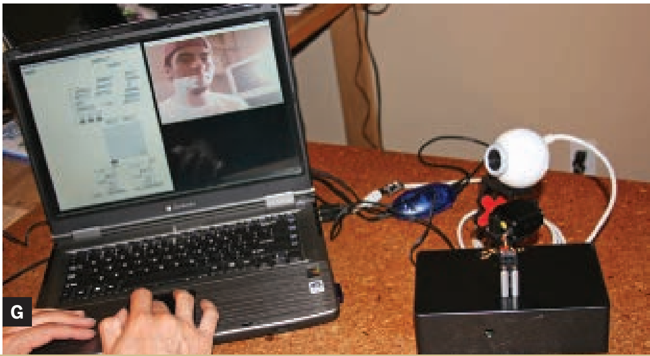


Fig. C: Measuring holes for mounting the servo assembly to the project box. Fig. D: Servo motor wires are threaded down to the ServoCenter board underneath. Fig. E: Motor connection to the ServoCenter; the board can handle up to 16 motors. Fig. F: Finished assembly of the MIDI cam unit. Fig. G: The MIDI cam system laptop runs VVVV to control camera movements and process live video feed.

Pan-Tilt MIDI Cam Unit

To make a nice, self-contained single camera unit I enclosed the ServoCenter board in a project box and attached the pan-tilt assembly on top. The webcam connects to the laptop, the pan-tilt servos connect to the ServoCenter, and the laptop connects to the ServoCenter through a USB-MIDI interface.

On the laptop, VVVV runs 2 separate workflows at once: one generates MIDI to control the servos, and one processes the video input from the webcams.

I drilled the top of the box and used 1¼" standoffs to attach the pan motor, which acts as the base of the pan-tilt assembly (Figure C). Inside, I mounted the ServoCenter board using ⅜" standoffs. The servo wires are threaded through another hole in top (Figure D), and holes in the side allow access to the ServoCenter's MIDI and power.

If your webcam has a stiff cord, a small servo might have trouble pushing it around; if so, cut away the insulation on the outside of the cord. Then mount the webcam on top of the pan-tilt assembly. I used a short ¼" bolt that threaded right into the cam's original mounting hole, but you could use any method that securely attaches the camera.

To start running your MIDI cam, download and install VVVV (vvvv.org), Midi Yoke, and MIDI-OX (both at midiox.com). Then download my script at makezine.com/19/diycircuits_midicams.

Run the core VVVV app, then open the script and see the embedded instructions, which explain how to set it up to move your cams, as well as use some other simple VJ functions to mix in images or videos.

VVVV is a graphical programming language that lets you build applications by drawing "building blocks," and linking them together. It's not your standard Windows program, so figuring it out takes a bit of reading the Help and poking around. But once you get the hang of it, it all makes sense; it has a logical, schematic-like workflow, so if you've ever read or drawn a circuit diagram, you should pick it up quickly.

If you have MIDI hardware, you can connect that to your laptop and use it to control your cameras through VVVV. Moving a physical knob or slider is better than poking around with a screen and keyboard, especially if you're performing live.

+ For project software and to see the MIDI cams in action: makezine.com/19/diycircuits_midicams

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By day, Josh Cardenas is a digital artist at ImageMovers Digital, but his background in computer graphics has led him into the VJ world. Witness his pixel-fu at visceralx.com.

EYE CONTACT DEVICE

Look more trustworthy while video-conferencing. By Don McLane

Services like Skype let you videoconference for free, but it never feels like a natural conversation. You see the other person staring down at the screen rather than looking at you. We humans are wired to look each other in the eye, and when someone doesn't, we naturally wonder if they're hiding something. Here's a setup that I use to make videoconferencing feel more like real face-to-face communication.

The Teleprompter Principle

My device is simply a box, open at each end, with a piece of glass splitting it diagonally and a hole in the top for a camera. It follows the same principle that teleprompters use to display text.

Size the box to just fit around your computer screen, and make it as deep as the screen is high. I used ⅝" particleboard shelving material, dowel pegs, and glue. Center a hole in the top that's large enough to give your webcam an unobstructed view of the mirror, and coat the interior with flat black paint to eliminate reflections.

The reflective pane should match the width of your screen, and be √2 (about 1.4) times as tall. To hold it, I cut diagonal slots with a table saw about ¼" deep into the sides of the box, on the inside. I also drilled holes and ran a dowel along the bottom, to keep the mirror from sliding out. To cushion it, I tucked a strip of pipe insulation underneath.

For the camera, USB webcams are best for family conferencing, since their wide-angle lenses will include everyone. For conferences between individuals, a camcorder lets you zoom in; WebCamDV software will route the camera's FireWire output to your videoconferencing application.

You can point the camera straight down, but I now use an SLR camera spy lens (right angle adapter) to fold the optical path like a periscope. This has the additional advantage of righting the image.

With your computer screen in back of the box and your camera on top, you're ready to go. Your friends will see you looking directly into their eyes. Yes, it's clunky, but no more so than those CRTs that we used not so long ago.

Photography by Don McLane

MATERIALS

- **Computer** the one you videoconference from
- **USB webcam, or FireWire camcorder and WebCamDV software** This $20 utility from OrangeWare (orangeware.com) turns a DV camcorder into a webcam.
- **Headset or echo-cancelling speaker/microphone** Audio will be a problem without one of these.
- **Box-making materials** to make a box that's sized to fit your computer screen (see tutorial at left)
- **Dowel** This runs across the bottom of the box to hold the mirror in, and you may need additional length to cut into pegs for joining the box.
- **Videoconferencing software** such as Skype, NetMeeting, Gmail, or Ekiga. I use AccessGrid, which is open source ware for group conferences.
- **Semi-reflective pane sized to fit in your box diagonally** For best results, use half-silvered glass or plexiglass (see telepromptermirrors.com), but a regular clear pane will also work, for one-tenth the price.
- **Flat black paint**
- **Lazy Susan (optional)** nice for changing position
- **Spy lens for SLRs (optional)** if using a camcorder

TOOLS

- **Table saw**
- **Drill and drill bits**
- **Hole saw** big enough for your camera to see through the hole without obscuring its view

Don McLane develops lab experiences at the University of Washington Tacoma that are (hopefully) educational and (hopefully) not life-threatening. He has a bachelor's degree in physics and a master's in electrical engineering.

DIY OUTDOORS

Photograph by Sam Murphy

GREENER WAVES

Surfboard kit uses a new epoxy technique without fiberglass.

By Keith Hammond

"Aren't we all tired of surfboards being as fragile as a porcelain doll? I can't think of any other piece of sporting equipment that is as easily destroyed."
—Board maker Matt Barker

Traditional surfboards are a frustrating old technology. First, they're toxic landfill — polyurethane foam, fiberglassed with polyester resin. Worse, they're fragile and short-lived because of cracks and leaks. That's ridiculous, and at $400 and up, expensive. Modern epoxy boards are stronger, and greener, but start at $600.

A DIY kit from Greenlight Surfboard Supply is the ticket. For $395 it's got all the materials and tools you need to make a tougher, greener epoxy board using expanded polystyrene (EPS) foam that's recyclable. Greenlight's new lamination technique, using stretchy bamboo fabric instead of fiberglass cloth, is easier and safer. And when this board finally fails I can recycle or compost most of it. Nice.

The layup uses a 2-part amine-cured epoxy resin from Resin Research. Their wetting agent, Additive F, helps the resin flow and "wet out" the cloth, and eliminates epoxy's tendency to "blush" or sweat in humid or cool conditions. This resin was designed for surfboards; it cures clear and it's UV-resistant.

I'm amazed at how pleasant it is to work with. It's got 1⁄50th the VOCs of polyester, so instead of choking on fumes, you can barely smell it. You use less, and it cleans up with water and citrus cleaner instead of acetone. What an improvement for the DIYer.

Greenlight co-owner Brian Gagliana says they experimented with natural fibers for a year before perfecting a layup with bamboo fabric. "We found that putting it in tension made it stronger and easier to laminate," he says, "as well as using less material."


A


B

Photography by Ed Troxell

MATERIALS AND TOOLS

Greenlight Deluxe Eco-Friendly Starter Kit $395 from greenlightsurfsupply.com. Includes 2lb/ft^3 EPS foam blank with laminated bamboo stringer, Resin Research 2000 epoxy resin, 2100F hardener, Additive F, bamboo "fiberglass" cloth, leash plug made of corn-based bio-plastic, fin boxes (or bamboo panel for shaping fins), inkjet/laser logo paper, and 5-DVD instructional video set, plus a handsaw, mini plane, Surform rasp, laminating roller, spackle, glue, dust mask, latex gloves, and all brushes, tapes, and sandpapers.
Surfboard template, and plans for shaping and glassing racks Download at greenlightsurfsupply.com/templates.html.
1×4 scrap wood: 12", 24" to make sanding blocks
2×4 lumber and wood screws to build a shaping rack and glassing racks
5gal buckets (2) and sand for glassing rack bases
Utility knife
Drill with 1¼" hole saw to mount the leash plug
Marker and pencil

Optional but recommended:
Calipers, T-square, framer's square for keeping things symmetrical. I made calipers from scrap plywood.
Handheld drop light for creating shadows to help shape the foam
Round rasp or round file if you make a swallowtail
Coping saw or jigsaw if you make fins
4½" angle grinder or Dremel rotary tool, with sanding disc for shaping fins and sanding down overlaps
Spring or ratchet clamps (2–3) for positioning fins
Distilled water for mixing spackle
Liquitex acrylic paint or similar, for pinlines

CAUTION: Spare your lungs and wear a respirator or particle mask when sanding EPS foam or epoxy. Wear disposable gloves and eye protection when working with epoxy resin; it can irritate skin and eyes, and can cause skin sensitivity with repeat exposure.

You can shape a board in a weekend, but plan on a week or two to glass it. Here I'll focus on the new glassing technique. For more on shaping, see makezine.com/19/diyoutdoors_epoxyboard, read Stephen Pirsch's how-to at surfersteve.com, visit the forums at swaylocks.com, and watch the Greenlight kit videos.

1. Get your kit and download a template.

I made a twin-fin "fish" with Greenlight's 6'6" kit. Whatever style you make, keep a similar board on hand for reference.

2. Glue and cut the foam blank.

Glue the blank halves to the stringer, as flush as possible. Trace the template on the bottom, saw it out, and square the rails with 36-grit sandpaper on your 12" sanding block.

3. Level the deck and bottom.

Plane down the stringer where it rises above the foam (Figure A), then use your 24" sanding block to level the foam and stringer on the bottom and deck (Figure B).

4. Shape foil and bottom contour.

For a thinner board, keep sanding. For steeper waves, you can put more "rocker" in the bottom. For easier turns, I put some "vee" in the tail.

5. Shape the rails.

Following Greenlight's diagrams, draw rail bands. Use the rasp to bevel the foam between bands (Figure C, following page), then use the 100-grit sanding screen to round the bevels into curves (Figure D). It works well!

The bottom edges are sharp in the tail (more bite

Fig. C: Use long strokes with the rasp to bevel the foam evenly between the rail bands you drew. Fig. D: A drywall sanding screen rounds off the rail bevels nicely. Fig. E: Sealing the EPS foam with lightweight spackle keeps it from absorbing excess epoxy. Fig. F: Use a chunk of scrap foam to make a jig for drawing lap lines. Fig. G: Stretch bamboo fabric across the bottom of the board, and stick it to the tape on the deck.

for turning), but rounded farther forward (more forgiving).

6. Blend the deck into the rails, nose, and tail.

With 60-grit on your 12" block, blend the deck into the rails and tail. To thin the nose, plane down the stringer, sand the foam down evenly, then blend.

7. Sand and spackle.

Sand the board with 80-grit on your foam sanding pad and remove any dust. To seal the EPS foam, mix lightweight spackle (DAP Fast 'n Final or Custom Patch-N-Paint) with water to the consistency of thin mayonnaise, then spackle the board, scrape away excess, and let it dry (Figure E). This type of spackle uses silica microcells as filler; pro shapers say it lets the epoxy resin penetrate and bond with the foam, but prevents the foam from soaking up too much.

8. Add artwork and fin boxes (optional).

Stick down artwork with resin, working out any bubbles. You can also paint your board using water-based acrylic or latex paints.

Most fin boxes are installed before laminating; follow manufacturer's instructions. Fin placement depends on board style, so copy a board or consult Greenlight or swaylocks.com.

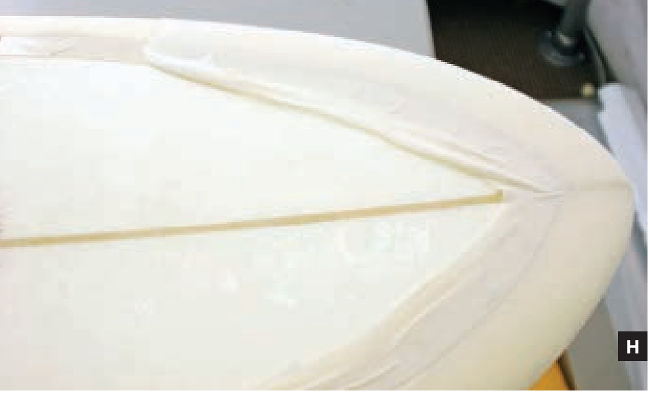
9. Laminate the bottom.

Pencil a lap outline on the deck 2½" from the edge, using a jig of scrap foam (Figure F). Lay down double-sided tape just inside this lap line; this is the deck tape.

Stretch bamboo cloth across the bottom, up over the rails, and down onto the deck tape (Figure G). Much easier than fiberglass! Pull it tight and smooth, with no wrinkles on the rails (Figure H). Minimize overlaps in the tail; you'll have to sand them out later. At the tail and nose, where it's tightest, tape excess fabric to the deck so it can't pull away.

Put on 2 pairs of latex gloves, and mix up 9oz of epoxy resin. The formula is 2 parts resin, 1 part hardener, and 1ml of Additive F per ounce of hardener. Measure carefully: too little hardener and the resin won't set; too much and it'll get hot and set in the bucket, "exotherming" in a chain reaction. Stir well for 1 minute.

CAUTION: Additive F is mostly xylene; keep it off your skin and don't breathe it.



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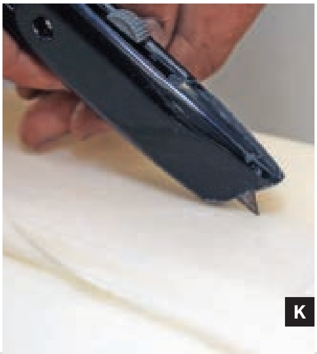


K

L

Fig. H: Keep stretching until all the wrinkles are off the rails, and behind the tape. Fig. I: Spread resin evenly to saturate the fabric, leaving no dry spots and working out any bubbles. Fig. J: Roll it. Moderate pressure with the laminating roller helps bond the epoxy to the foam. Fig. K: Score the lamination along the lap line, peel up the tape, and snap off the excess fabric. Fig. L: Shim the clamps to hold fins at the correct cant angle.

Using a paintbrush, saturate the rails, work out any bubbles, and pull off the excess resin. Flip the board, and toss the first pair of gooey gloves. Saturate the entire bottom using the plastic spreader, working small areas from stringer to rails (Figure I). Leave no dry spots. Mix more resin as needed.

Run the laminating roller over it all with moderate pressure; this strengthens the bond between the epoxy and foam (Figure J). Let it cure.

With a small block and 60-grit, sand down any wrinkles or overlaps on your rails. Score along the lap line with a utility knife, then peel the tape up and snap off the excess fabric (Figure K). Sand the lap flush to the deck foam, and remove all dust.

10. Laminate the deck patch.

Reinforce ⅔ of the deck: put double-sided tape outside the lap line, stretch bamboo fabric onto it, and laminate with 9oz resin. Sand the laps flush to the foam, and remove any dust.

11. Shape and laminate fins (optional).

Cut fins from the bamboo panel with a coping saw. Foil them using a grinder, Dremel, or 60-grit block. Laminate in bamboo fabric, and sand with 80-grit.

12. Laminate the full deck.

Draw a lap line on the bottom, put down double-sided tape inside this line, and laminate the entire deck and rails, as you did the bottom. Start with 9oz of resin; you'll probably use 18oz.

Score carefully — don't cut your bottom lamination. Sand laps flush. Congratulations: your board is "glassed" in bombproof epoxy, with double-strength rails and deck patch. Lightly sand with 60-grit on your foam pad, and remove dust.

13. Paint pinlines (optional).

It's traditional to hide lap lines under painted "pinlines" about 3⁄16" wide. Use masking tape and acrylic paint, and pull up the tape while it's wet.

14. Glass on the fins.

Use clamps to hold the fins at your chosen toe-in and cant angle, as you glue them on with resin thickened with bamboo dust (Figure L). Let it cure.

Strengthen the fin bases with "fillets" of resin: make a masking-tape dam around one side of each base, then tip the board on its side and pour a little resin along the bases, building them up ⅛"–¼". Repeat on the other side. Sand them nice and round using a pencil wrapped in 80-grit.

Fig. M: When hot-coating, use long, light strokes to spread the resin. A little extra pressure in the curve of the deck will help keep resin from pooling there. Fig. N: A dam of masking tape creates a nice sharp edge in the tail. Fig. O: Drip resin around the leash plug, wait awhile for bubbles to rise, then drip a little more if needed. Fig. P: Your board will be strongest if you let the epoxy cure 7 full days — if you can wait that long.

Photograph by Sam Murphy (P)

15. Hot-coat the board.

"Hot coat" is shaper-speak for the second coat of polyester resin, formulated to cure quicker, generating heat. Your epoxy hot coat won't get hot, but serves the same purpose: to smooth the board and fill in the lamination texture.

Lightly sand with 120-grit and remove dust. Mix 12oz of resin with double Additive F (2ml per ounce of hardener). Paint the deck and rails, forcing resin into the fabric texture. Go over it again lightly to spread it evenly, letting the brush do the work (Figure M). Scrape drips off the bottom, and let it cure.

Flip the board, sand down drips, and remove dust. Run masking tape around the rail just below the centerline, to save the deck from drips. Around the tail, add a resin dam of masking tape, sticking up; this will make a nice sharp edge (Figure N). Now paint the bottom and fins with 12oz of resin. Let it set 2 hours, then pull off the drip tape and let it cure.

16. Sand the hot coat.

Sand the board well with 80-grit, then 120, on up to 220. A power sander is handy, but go easy. Use the foam sanding pad on the rounded rails, and a hard block on the sharp rails. Hand-sand the fins.

17. Install the leash plug.

Cut a 1¼" hole ⅝" deep in the deck, on the stringer a few inches from the tail. Clean the hole so the leash plug fits flush to the deck. Pour in a bit of resin thickened with bamboo dust, place the plug, and patiently drip resin around it to fill the gap (Figure O). Let it cure and sand it flush.

18. Gloss-coat the board (optional).

Paint a thin coat of resin mixed with double Additive F, and let it cure. Sand with 320-grit and buff to a mirror polish. Go surfing!

Special thanks to Brian Gagliana at Greenlight Surfboard Supply for friendly advice and encouragement.

Keith Hammond is copy chief of MAKE.

Long Cord Storage

My shop vac came with a very long cord, so I made a simple bracket from PVC pipe for winding it up. If I wind it in a figure-eight pattern, it won't be all twisted and tangled when I unwind it because the coils reverse as I wind it on.

—*Frank Ford*, frets.com/homeshoptech

Find more tools-n-tips at makezine.com/tnt.

1+2+3 Easy Boombox

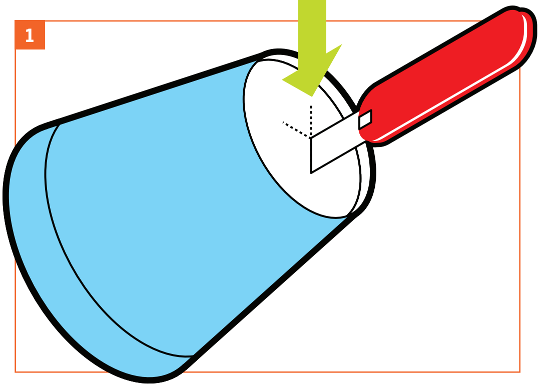
By Matthew T. Miller

You can make it!

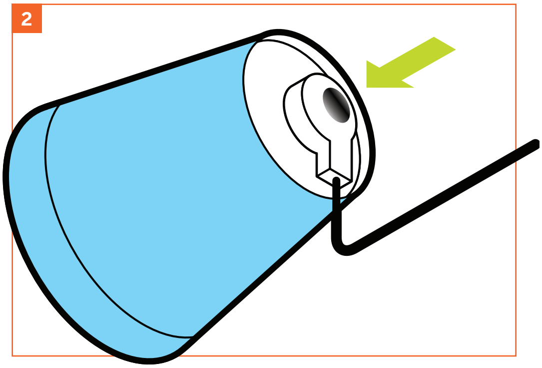
Many earbuds can play at high volume without distortion. Use them to drive paper cups, and the sound is surprisingly good. I first put this together when I really needed to listen to some jams at work. Put the ghetto back into the blaster!

YOU WILL NEED

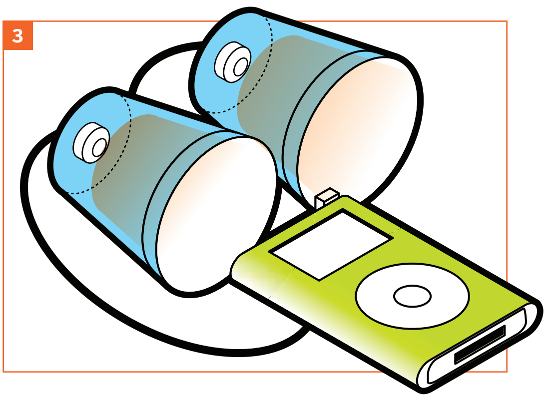
Earbuds
Paper cups
Pocketknife
Audio source



1. Prepare the cups.
Cut small Xs in the bottoms of 2 paper cups.



2. Insert the earbuds.
Carefully insert the earbuds into the Xs. They should fit snugly.



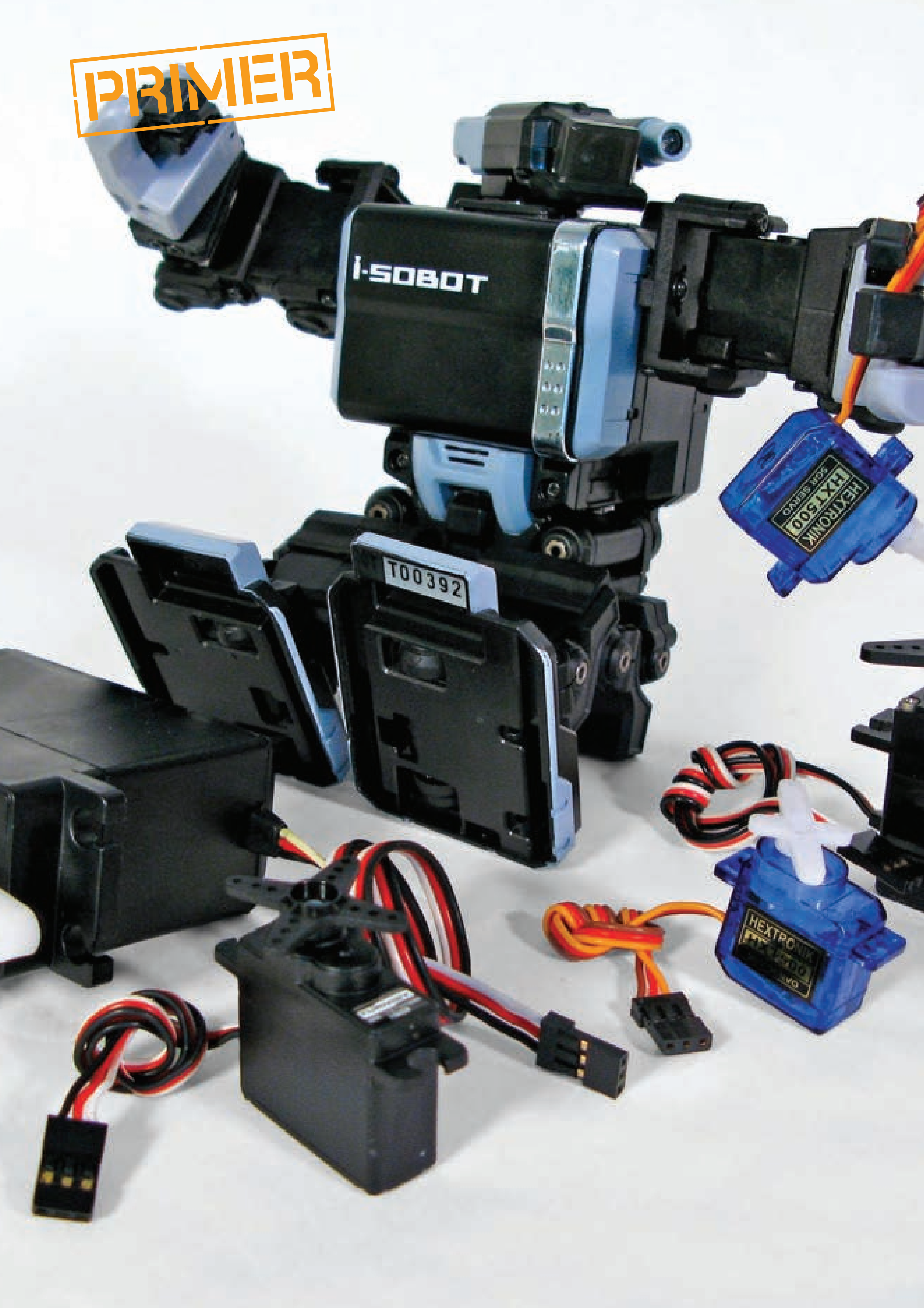
3. Turn on the jams and rock out.
See how much amplification you can get out paper cups!

Use It.
My earbuds do play at very high volumes without distortion ... so the sound from my ghetto blaster is actually really good. This is a cheap, easy trick and will save you serious money.

Illustrations by Julian Honoré; photograph by Matthew T. Miller

Matthew Teague Miller is a 36-year-old father who lives in San Pedro, Calif. He loves to create things out of household objects.

PRIMER



SERVO-MOTORS

Beef up on robotic musculature.

By Tod E. Kurt

You've seen them in robots and toys, or at least heard the distinctive *zzt-zzt-zzt* sound that accompanies their movement. R/C servomotors, designed for use in radio-controlled hobby cars and planes, are a common tool for robotics, movie effects, and puppeteering.

Servos don't spin like normal motors, but instead rotate and stop at a commanded position between 0 and 180 degrees. They're one of the easiest ways to add motion to a project, and there are many different kinds of servos to choose from.

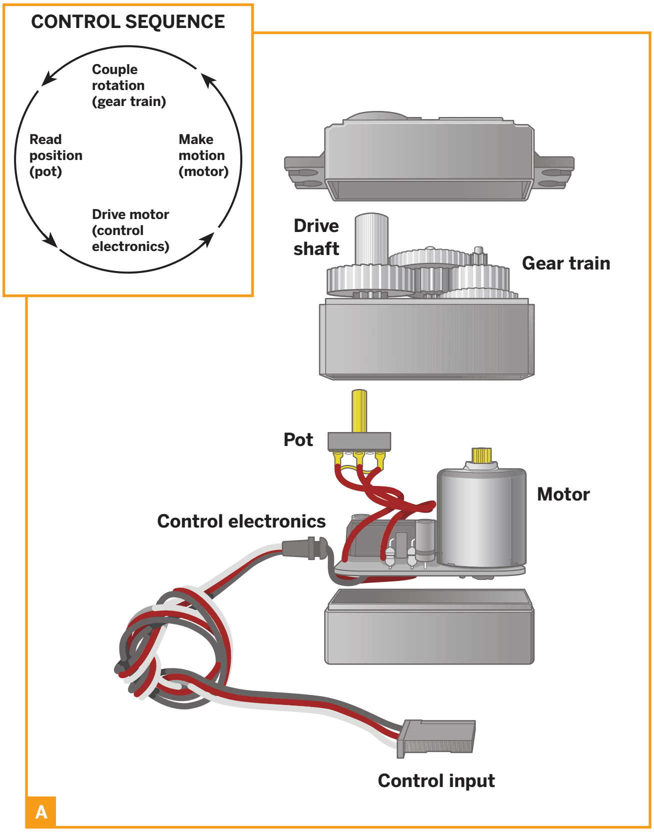
Servos can also be hacked to create high-quality, digitally controlled, variable-speed gearmotors, with a few simple modifications. In this article I'll explain the basics of how to use servos, and how to hack them to make continuous rotation servos as well.

Photography by Tod Kurt

UNDERSTANDING SERVOS

R/C servomotors (or just "servos") are packed with technology, including a DC motor, gear train, sensor, and control electronics. They are a kind of *servomechanism*. Servomechanisms use a *feedback control loop* to adjust how a mechanism functions. One example of a servomechanism is a thermostat-controlled heating system. The temperature-sensing thermostat is the feedback-providing sensor, and the heating element is the output. The heater gets turned on and off based on the temperature sensing.

For R/C servos, the sensor input is a potentiometer (or "pot" for short) that's used to measure the amount of rotation from the output motor. Control electronics read the electrical resistance of the pot and adjust the speed and direction of the motor to spin it toward the commanded position. Figure A shows an exploded view of a standard servo and the workings of the servo's closed feedback control loop.



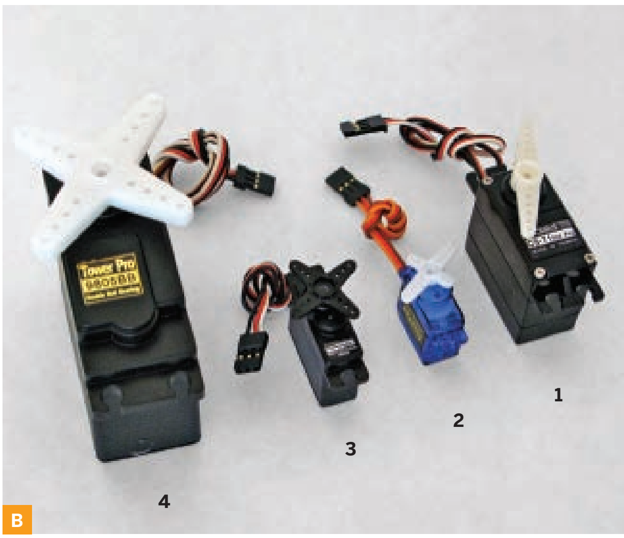
A

SELECTING SERVOS

Servos come in a variety of shapes and sizes (Figure B). The most common class of servo is the *standard* servo (1). The smallest servos are the *micro* class (2, 3), and the largest are the *high-torque/winch* class (4). All of these have the same 3-wire control, so it's easy to move to a bigger or smaller servo as your needs change.

Besides their dimensions and weight, servos are characterized by two main attributes: *torque* and *speed*, determined by the gearing and the motor in the servo.

The torque is essentially the strength of the servo. A standard servo torque value is 5.5kg/cm (75oz/in) when



B

Illustrations by Damien Scogin

operating at 5V. The speed is how fast the servo can move from one position to another. A standard speed is 0.20 seconds to move 60° at 5V. In general, the larger servos are slower but more powerful.

Until you know exactly what you need, it's easier to pick a size class (standard/micro/winch) and then choose the cheapest one in the list. For these projects, I use the micro HexTronik HXT500 servo, rated at 0.8kg and 0.10sec. I got them for under $4 each at hobbyking.com. They're cheap and they work well.

SERVO MOUNTING AND LINKAGES

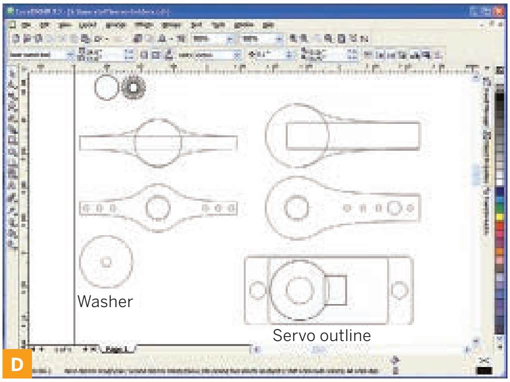
To move something with a servo, you need two things: a mount for the base and a linkage to join the drive shaft to what needs to be moved. Servos come with mounting holes in their bases for screw mounting. For experimenting, it's easier to use hot glue or double-sided foam tape to hold a servo in place.

To connect the drive shaft, servos come with a collection of adapters called *servo horns*. These fit over the shaft and have an arm with mounting holes. By connecting a rod or wire to a mounting hole, you can turn the servo's rotary motion into linear motion. Choosing different servo horns or mounting holes will provide larger or smaller amounts of motion.

Figure C shows a collection of different types of servo horns. The 4 white ones in front of the servo are stock horns, and the 4 on the right are DIY horns cut from plastic on a laser cutter. The 2 at far right are a combination of horn and mount, allowing the chaining together of servos.

Creating custom horns is easy. Use a vector art program to make a star shape with the diameter and number of points matching the drive shaft of your servo. That star becomes the shaft connector, and any other kind of custom linkage can be added around that (Figure D).


C

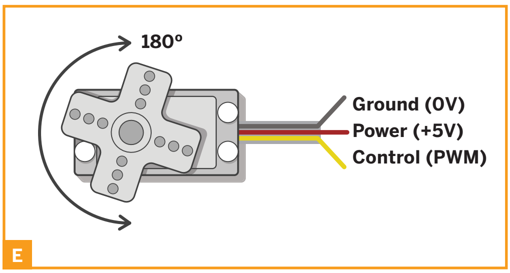


D

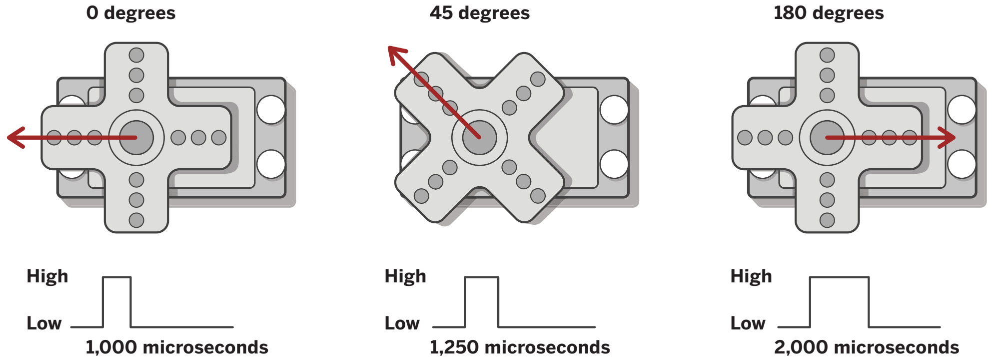
HOW TO CONTROL A SERVO

Servos have a 3-wire interface, as shown in Figure E. The black (or brown) wire connects to ground, the red wire to +5V, and the yellow (or white or orange) wire connects to the control signal.

The control signal (shown in action in Figure F, following page) is a type of *pulse-width modulation* (PWM) signal, easily produced by all microcontrollers. For this article I used the common



E



F

Arduino microcontroller.

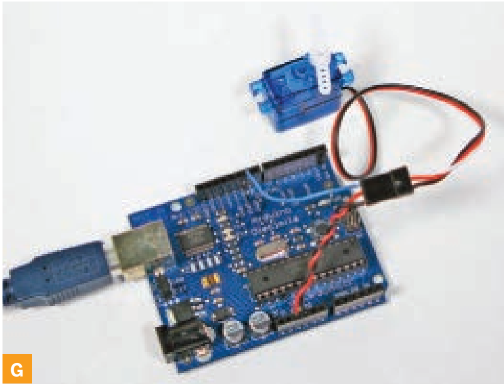
The HIGH part of the pulse lasts between 1 and 2 milliseconds (ms), equal to 1,000 to 2,000 microseconds (μs). At 1,000μs, the servo will rotate to its full anti-clockwise position. At 2,000μs, it will rotate to its full clockwise position. Some servos accept shorter or longer pulses and have a correspondingly larger rotational range.

The LOW part of the control pulse lasts for 20 milliseconds. Every 20ms (50 times per second), the HIGH pulse must be received again or the servo will de-energize and not hold its position. This is useful if you want your project to "go limp."

Below is a complete Arduino sketch that will continually position the servo at its midpoint. Controlling a servo is pretty easy.

```
int servoPin = 9;
int servoPosition = 1500; // position in microseconds
void setup() {
 pinMode(servoPin, OUTPUT);
}
void loop() {
 digitalWrite(servoPin, HIGH);
 delayMicroseconds(servoPosition);
 digitalWrite(servoPin, LOW);
 delay(20); // wait 20 milliseconds
}
```

Wire up the servo as in Figure G. Red and black wires go to the Arduino's 5V power and Gnd pins. The control wire goes to digital input/output pin 9.


G

The problem with this Arduino sketch is that it spends most of its time stuck in the delay commands. Fortunately, the Arduino's built-in Servo library lets you control 2 servos (on pins 9 and 10) using its built-in timers, and frees up your code to do other things. The same sketch using the library would be:

```
#include <Servo.h>
Servo myservo;
void setup() {
 myservo.attach(9); // servo is on pin 9 like before
 myservo.write(90); // set servo to 90 degree position
}
void loop() {
 // free to do anything, our servo is still being driven for us
}
```

USING SERVOS: PAN-TILT HEAD FOR WEBCAMS

Here's a quick project using 2 servos and an Arduino: a pan-tilt head for a webcam. Hot-glue a servo horn to the bottom of the webcam. Hot-glue another horn to the side of one servo. Hot glue the other servo to a base. Then plug all the servo horns into the servos and you've got a pan-tilt webcam.

Figure H shows an example: a homebrewed network pan-tilt webcam built from an Asus wi-fi router running OpenWrt Linux. Both the webcam and the Arduino controlling the servos are connected via a small USB hub to the router's USB port .

The code to control 2 servos from the Arduino's USB/serial port is shown below. The sketch waits for 2 bytes to arrive over the serial port, then treats the first byte as the 0–180 value for the pan servo and the second as the 0–180 value for the tilt servo.

H

```
#include <Servo.h>
Servo servoPan;
Servo servoTilt;
void setup() {
 servoPan.attach(9); // pan servo is on pin 9
 servoTilt.attach(10); // tilt servo is on pin 10
 servoPan.write(90); // home both servos to center
 servoTilt.write(90); // home both servos to center
}
void loop() {
 if( Serial.available() >= 2 ) { // two bytes waiting for us
 int pan = Serial.read(); // 1st byte is Pan position
 int tilt = Serial.read(); // 2nd byte is Tilt position
 servoPan.write(pan);  // move pan servo
 servoTilt.write(tilt);  // move tilt servo
 }
}
```

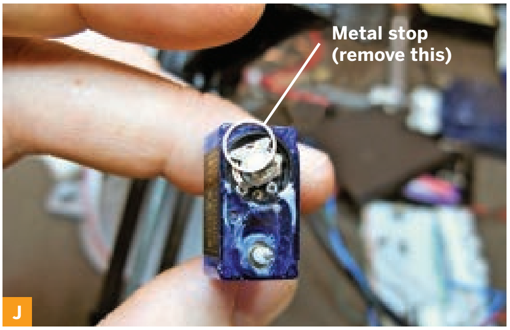
MODIFYING SERVOS FOR CONTINUOUS ROTATION

Any servo can be turned into a bidirectional, variable-speed gearmotor. Normally, controlling a motor's speed and direction requires a motor driver chip and other parts. A servo already contains all these parts. Hacking it is one of the best-known and cheapest ways to get a digitally controlled gearmotor for use in robotics — a *continuous rotation servo*.

The modification is part mechanical and part electrical. The electrical mod replaces the pot with 2 fixed resistors of equal value. The mechanical mod removes the stops that prevent the motor from rotating fully.

I

NOTE: If you don't want to open up a servo, Parallax (maker of the BASIC Stamp) has a ready-to-use, standard-sized continuous rotation servo.



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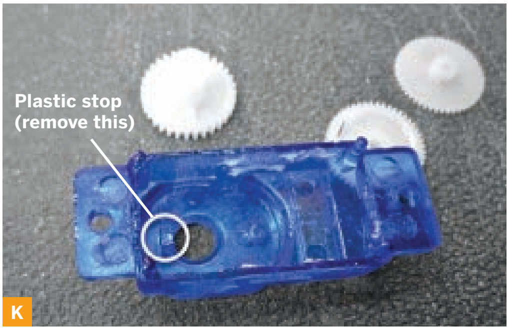
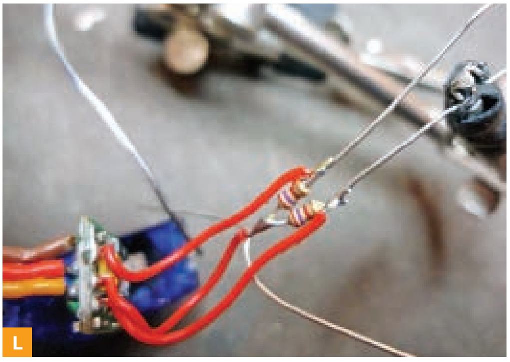


K



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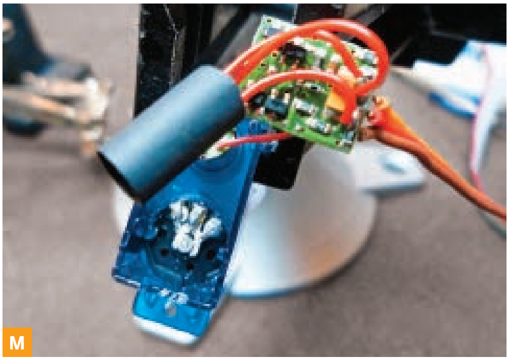
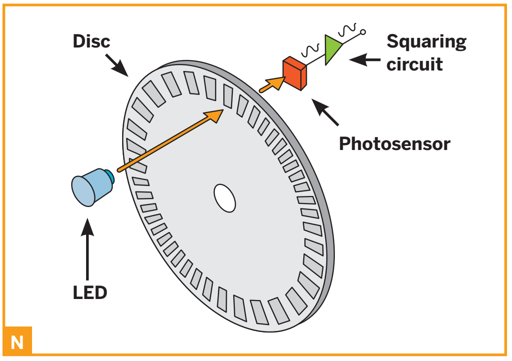


M



N

First, open up the servo. The HTX500 servo case is made of 3 plastic pieces press-fit together. You can use a small blade screwdriver or similar thin wedge to separate them. From the top, pull off the gears (note which ones go where). From the bottom, carefully pull out the servo's circuit board (Figure I).

There are 2 mechanical stops. Remove the metal stop at the shaft base by bending it with needlenose pliers (Figure J). Remove the plastic stop on the top case with diagonal cutters (Figure K).

Replace the 5kΩ pot with 2 fixed resistors that add up to near 5kΩ. A pair of 2.2kΩ resistors works well. Unsolder the 3 wires from the servo's pot and solder them to the 2 resistors as pictured in Figure L. Wrap this new assembly in electrical tape or heat-shrink tubing (Figure M). Tuck it and the rest of the electronics back into the servo case and snap it all back together.

That's it for the hack. Calibrate your finished continuous servo by finding where the *zero point* is. If the 2 fixed resistors were exactly identical, a 90° angle sent to the servo would make the motor stop. Your servo's value will likely be a bit off. You can use the previous sketch to experiment in finding what angle does stop the motors. Remember that value, because it'll be different for each servo.

Hobby servos use potentiometers to measure shaft rotation. Servos used in larger systems like industrial robots and CNC machines use rotary encoders. Optical rotary encoders attach a disc with slits and count the number of slits that go by with an LED and photosensor (Figure N). This is also how mechanical ball computer mice measure movement.

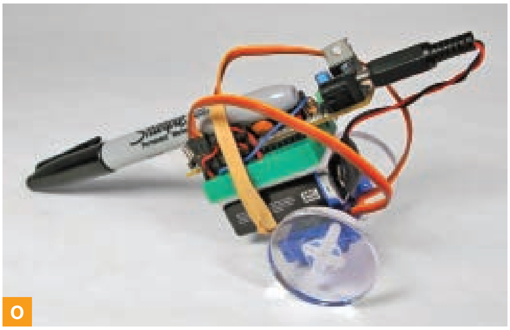
5-MINUTE DRAWBOT PROJECT

With two continuous rotation servos, you can start making robots. Figure O shows a drawbot made from two servos, a 9V battery, a small breadboard, an Adafruit Boarduino (Arduino clone), a Sharpie marker, and a couple of plastic discs.

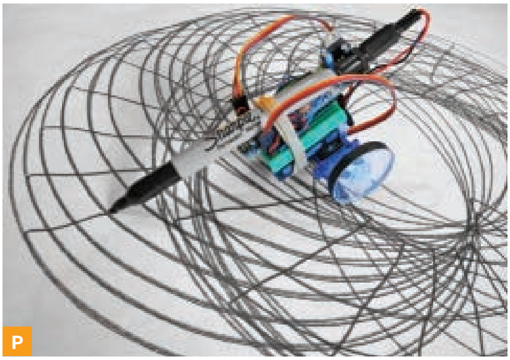
The circuit is the same as for the pan-tilt head, and all the parts can be held together with hot glue. For wheels, any disc that's 1"–3" in diameter should work, such as plastic screw-top lids. To increase traction, wrap the wheel edges with duct tape.

The servos are set up as before. The sketch uses variables that contain the experimentally determined zero values to stop the motors. (Your zero values will be different.) The logic of this sketch runs one motor in one direction for a period of time, then switches to the other motor. The result is a Spirograph-like shape (Figure P).

```
#include <Servo.h>
Servo servoL;
Servo servoR;
int servoLZero = 83;  // experimentally found to stop
L motor
int servoRZero = 91;  // experimentally found to stop
R motor
boolean turnleft = false;
void setup() {
 servoL.attach(9);
 servoR.attach(10);
 servoL.write(servoLZero);  // start out not moving
 servoR.write(servoRZero);  // start out not moving
}
void loop() {
 turnleft = !turnleft;
 if( turnleft ) {
  servoL.write( servoLZero - 10 );
  servoR.write( servoRZero );
  delay(1000);
 } else {
  servoL.write( servoLZero );
  servoR.write( servoRZero + 10 );
  delay(4000);  // turn more one way than the other
 }
}
```



O

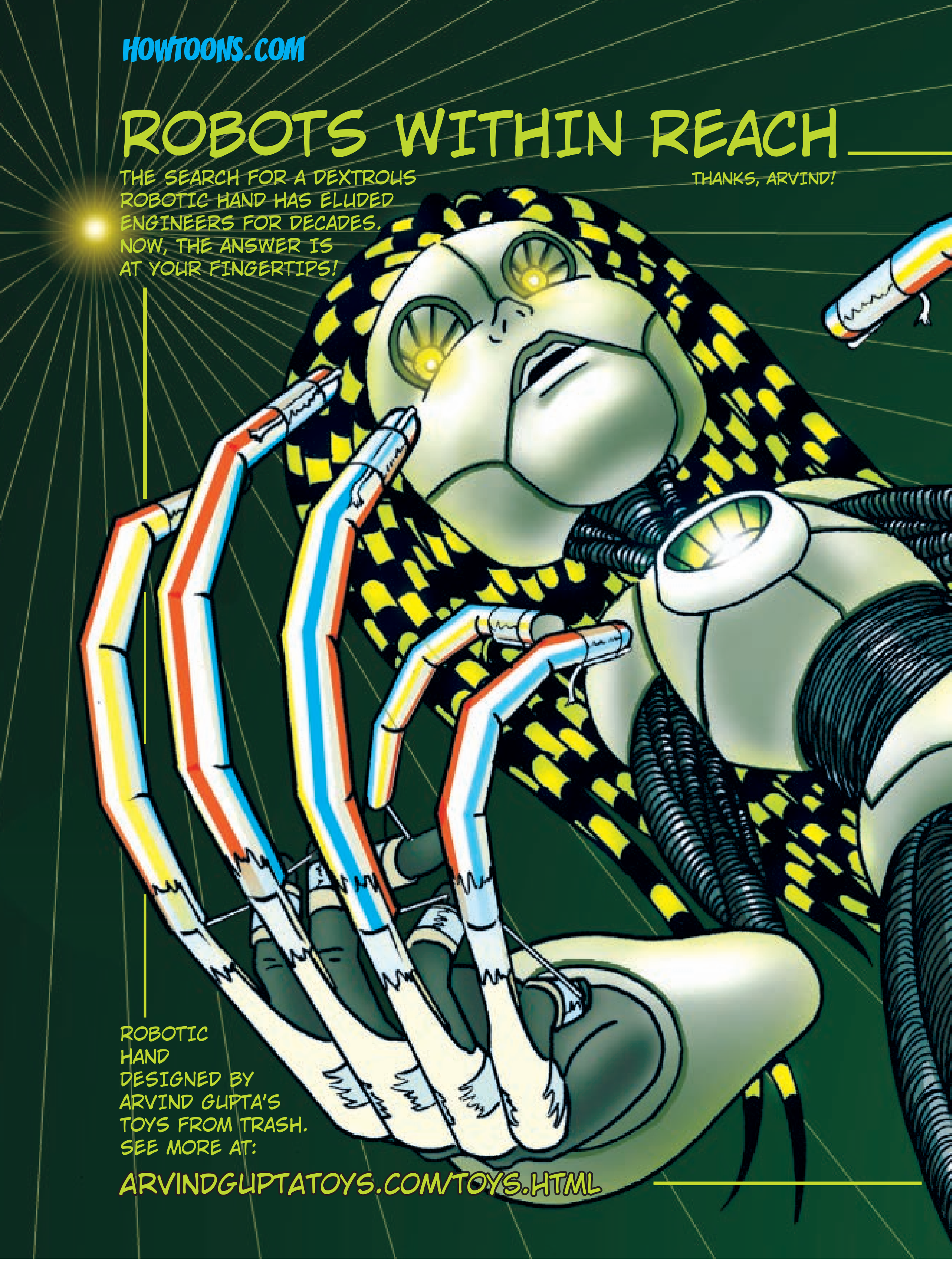

P

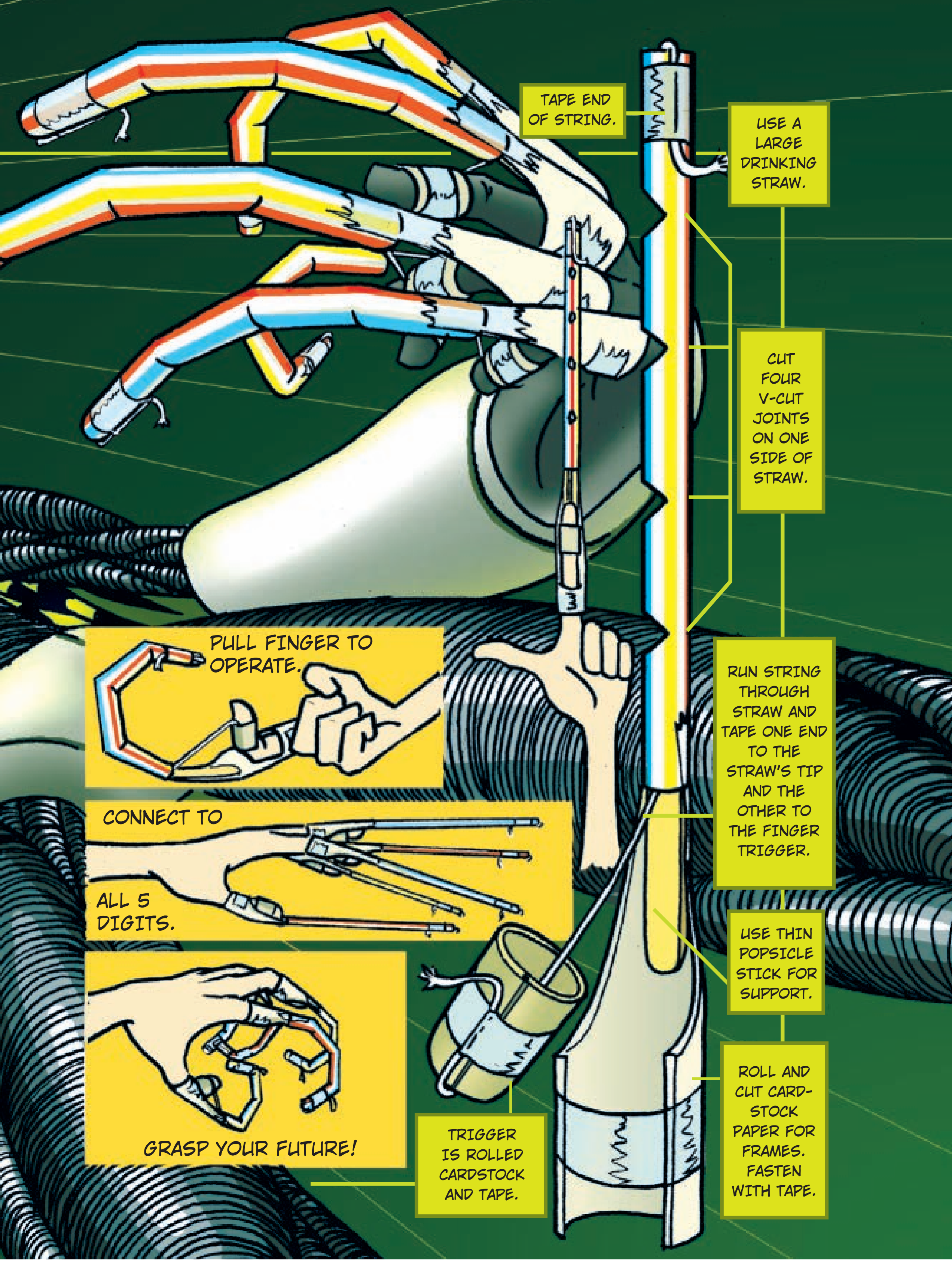
NOTE: The Sharpie is a permanent marker, so be sure to run the drawbot on top of cardboard or layers of butcher paper, or substitute water-soluble markers.

RESOURCES

- **Hobby People (hobbypeople.net) is a good U.S.-based vendor of servos.**
- **HobbyKing (hobbyking.com), formerly HobbyCity, is a China-based servo vendor with a huge selection.**
- **Adafruit (adafruit.com) carries Arduino and Boarduino microcontrollers, and Parallax continuous servos.**
- **Trossen Robotics (trossenrobotics.com) carries Parallax continuous servos and many other neat robot things.**
- **Oomlout SERB robot (oomlout.com/serb.html) is an open source robot base that uses continuous servos.**
- **Servo hacks on Instructables (instructables.com): Do a search for "servo" to see many more servo projects.**

Tod E. Kurt (todbot.com/blog) is co-founder of ThingM, makers of the BlinkM Smart LED (blinkm.thingm.com), and author of *Hacking Roomba* (hackingroomba.com), an introductory robotics course disguised as a set of vacuum cleaner hacks.


HOWTOONS.COM
ROBOTS WITHIN REACH
THE SEARCH FOR A DEXTROUS ROBOTIC HAND HAS ELUDED ENGINEERS FOR DECADES. NOW, THE ANSWER IS AT YOUR FINGERTIPS!
THANKS, ARVIND!
ROBOTIC HAND DESIGNED BY ARVIND GUPTA'S TOYS FROM TRASH. SEE MORE AT:
ARVINDGUPTATOYS.COM/TOYS.HTML


TAPE END OF STRING.
USE A LARGE DRINKING STRAW.
CUT FOUR V-CUT JOINTS ON ONE SIDE OF STRAW.
RUN STRING THROUGH STRAW AND TAPE ONE END TO THE STRAW'S TIP AND THE OTHER TO THE FINGER TRIGGER.
USE THIN POPSICLE STICK FOR SUPPORT.
ROLL AND CUT CARD-STOCK PAPER FOR FRAMES. FASTEN WITH TAPE.
TRIGGER IS ROLLED CARDSTOCK AND TAPE.
PULL FINGER TO OPERATE.
CONNECT TO
ALL 5 DIGITS.
GRASP YOUR FUTURE!

RETROSPECT
By George Dyson

Cottage Economy

Pamphleteer William Cobbett launched the sustainability movement — in 1821.

» "The word Economy, like a great many others, has, in its application, been very much abused," explained William Cobbett, the irrepressible British (and at times North American) radical agitator and pamphleteer, in the introduction to *Cottage Economy*.

Cobbett (1763–1835) was one of the leading social commentators of the post-Revolutionary period in England and the United States, when the business of today's bloggers was conducted by pamphleteers. Cobbett's *Political Register* was pre-Victorian England's *Huffington Post*. But the stakes were high, and a charge of sedition over one of his postings, exposing corruption in the military, earned him two years in Newgate Prison.

Cobbett took advantage of his imprisonment to write one of his more inflammatory monographs, *Paper Against Gold; or, The History and Mystery of the Bank of England, of the Debt, of the Stocks, of the Sinking Fund, and of all the other tricks and contrivances, carried on by the means of Paper Money*.

"There was, to be sure, when people looked into the matter more closely," he observed, "something rather whimsical in the idea of a *nation's paying interest to itself*; something very whimsical in a nation's GETTING MONEY by *paying itself interest upon its own stock.*"

Cobbett, who was born into a family of rural farmers and began working in the fields at the age of 6, grew increasingly enraged over the mistreatment and growing impoverishment of the working poor, who, in the shift from agriculture to industry, were being forced to buy (and pay heavy taxes on) things they had formerly been able to make, and grow, for themselves. *Cottage Economy*, written as a series of pamphlets and later assembled into a book, was an attempt to shift the trend the other way.

"I propose to treat of brewing Beer, making Bread, keeping Cows and Pigs, rearing Poultry, and of other matters; and to show that while from a very small piece of ground a large part of the food of a considerable family may be raised, the very act of raising it will be the best possible foundation of education of the children of the labourer," Cobbett wrote. "And is it not much more rational for parents to be employed in teaching their children how to cultivate a garden, to feed and rear animals, to make bread, beer, bacon, butter, and cheese, and to be able to do these things for themselves, or for others, than to leave them to prowl about the lanes and commons, or to mope at the heels of some crafty, sleek-headed pretended saint, who while he extracts the last penny from their pockets, bids them be contented with their misery, and promises them, in exchange for their pence, everlasting glory in the world to come?"

To Cobbett, who estimated "that we use, in my house, about seven hundred gallons of beer every year," the demise of home brewing epitomized the subjugation of the working class. In former times, he wrote, "to have a house and not to brew was a rare thing indeed," whereas workers were now forced to purchase beer instead of making it.

"The causes of this change have been the lowering of the wages of labour, compared with the price of provisions, by the means of the paper money; the enormous tax upon the barley when made into malt; and the increased tax upon hops," Cobbett explained. "These have quite changed the customs of the English people as to their drink. They still drink beer, but, in general, it is of the brewing of common brewers, and in public houses, of which the common brewers have become the owners, and have thus, by the aid of paper money, obtained a monopoly in the supplying of the great body of the people with one of those things which, to the hard-working man, is almost a necessary of life."

Cottage Economy offered practical and detailed instructions to "prepare for the making of beer in our own houses, and take leave of the poisonous stuff served out to us by common brewers." This included a diatribe against the evils of tea, arguing at length "that tea has no useful strength in it; that it contains nothing nutritious; that it, besides being

WHY BUY? Radical DIY author Cobbett advised making one's own bread, bacon, cheese, vegetable garden, and especially, beer.

Cottage Economy has remained in print for 188 years, and is now freely available, in digital facsimile, from the Internet Archive and Google Books.

good for nothing, has badness in it, because it is well known to produce want of sleep in many cases, and in all cases, to shake and weaken the nerves."

With brewing out of the way, Cobbett proceeded to demonstrate, in detail, "that a large part of the food of even a large family may be raised, without any diminution of the labourer's earnings abroad, from forty rods, or a quarter of an acre, of ground."

He tackled the growing of cabbages, turnips, and mustard ("Why buy this, when you can grow it in your garden? The stuff you buy is half drugs, and is injurious to health.") as well as the raising of chickens, and the husbandry of goats, cows, and pigs.

He praised the compost heap: "Every thing of animal or vegetable substance that comes into a house, must go out of it again, in one shape or another. The very emptying of vessels of various kinds, on a heap of common earth, makes it a heap of the best of manure."

Cobbett advised milling one's own flour and gave instructions for making bread, acknowledging that "it would be shocking indeed if that had to be taught by the means of books," and adding that "many women in England, who seem to know no more of the constituent parts of a loaf than they know of those of the moon ... appear to think that loaves are made by the baker, as knights are made by the king."

Potatoes are viewed as an evil almost as great as tea, a food that forces the impoverished to live like animals who "scratch them out of the earth with their paws," while the family that bakes its own bread has "bread always for the table, bread to carry afield; always a hunch of bread ready to put into the hand of a hungry child."

To counter the ruinous tax on candles, Cobbett explained how to illuminate the cottage by burning rushes soaked in grease, noting that "my grandmother, who lived to be pretty nearly ninety, never, I believe, burnt a candle in her house in her life."

He included a lengthy treatise on preparing native grasses for weaving into straw hats, advice on milking cows and goats, and a series of tips on raising (and eating) rabbits and geese. He examined the advantages of barter, noting that the cottager "ought to pay for nothing in money, which he can pay for in any thing but money." He explained (and illustrated) the construction of large, circular, heavily insulated icehouses, in which ice cut in the wintertime can be kept for use during the hottest part of the year.

A mouthwatering chapter is devoted to the preparation of bacon, covering every step along the way, from the breeding to the fattening of hogs to the best way to singe the hair off the freshly-slaughtered sides, and the best manner in which to salt and then smoke-cure the resulting bacon.

"Meat in the house is a great source of harmony," noted Cobbett. "A couple of flitches of bacon are worth fifty thousand Methodist sermons and religious tracts. The sight of them upon the rack tends more to keep a man from poaching and stealing than whole volumes of penal statutes."

To William Cobbett, who rose to become a member of Parliament in later life, cottage economy remained the foundation upon which the health and wealth of the nation rests. "There never yet was, and never will be, a nation permanently great, consisting, for the greater part, of wretched and miserable families," he wrote.

All of us, rich and poor, would do well to revisit his advice.

George Dyson, a kayak designer and historian of technology, is the author of *Baidarka*, *Project Orion*, and *Darwin Among the Machines: The Evolution of Global Intelligence*.

By Lee D. Zlotoff

Against the Wind

The Scenario: You're an experienced and avid open-ocean kayaker, setting off early from your favorite coastal launch point for a restorative and invigorating day on the water. You've checked with the Weather Channel and the National Weather Service, and both have predicted sunny weather, slight clouds, and virtually no wind. So, after donning some sunblock and checking your gear and supplies, you're off.

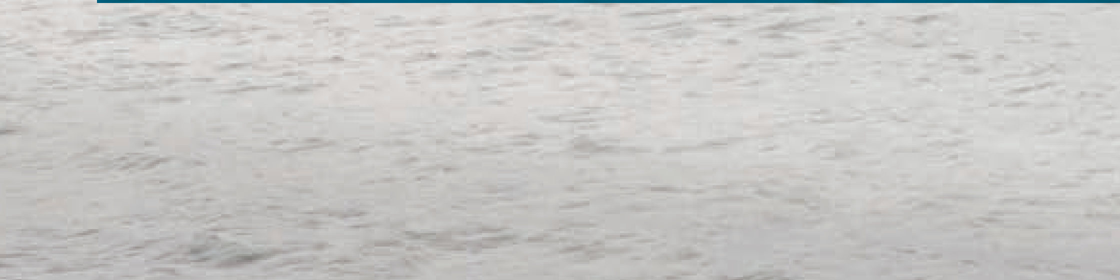
The launching goes OK, but you take on a little water fighting the breakers. When you finally clear them, you paddle steadily until you're about 1 mile offshore, which you confirm with your GPS. Venturing out a little farther, you paddle parallel to the shore for a few hours. Then, adjusting your life vest and seat cushion to make yourself more comfortable, you stop to relax and enjoy the scenery, but between the warm sunshine, the gentle roll of the ocean, and the hypnotically reflective water, you nod off.

The Challenge: When you wake several hours later, the ocean is choppy and a strong, southerly wind has picked up, which has pushed you at least 3 miles from shore and continues to grow in strength. You dig for your cellphone just in case you need to call for help, only to discover that the saltwater you took on earlier has rendered it useless. You paddle hard for shore, but even after a relentless hour, the winds and currents seem to erase all your progress and the tall beachfront hotels are becoming mere dots on the horizon. You realize more paddling might be fruitless and only exhaust you completely. So what do you do now?

What You've Got: Two gallons of fresh drinking water and a basic survival kit with a compass, a lightweight 6×7-foot survival blanket (silvered on one side and dark on the other, in a pouch), heavy-duty nylon tape, and a coil of thin but strong nylon rope. You've also got a Swiss Army knife (or similar tool), some marine binoculars, a GPS unit, your waterlogged cellphone, some basic medical supplies in their own self-contained marine emergency medical kit, and an extra paddle. You also have a lightweight, waterproof windbreaker and some foul-weather gear stashed in the small but useful front storage compartment.

Send a detailed description of your MakeShift solution with sketches and/or photos to makeshift@makezine.com by Nov. 20, 2009. If duplicate solutions are submitted, the winner will be determined by the quality of the explanation and presentation. The most plausible and most creative solutions will each win a MAKE T-shirt and a *MAKE Pocket Ref*. Think positive and include your shirt size and contact information with your solution. Good luck! For readers' solutions to previous MakeShift challenges, visit makezine.com/makeshift.

Lee David Zlotoff is a writer/producer/director among whose numerous credits is creator of *MacGyver*. He is also president of Custom Image Concepts (customimageconcepts.com).

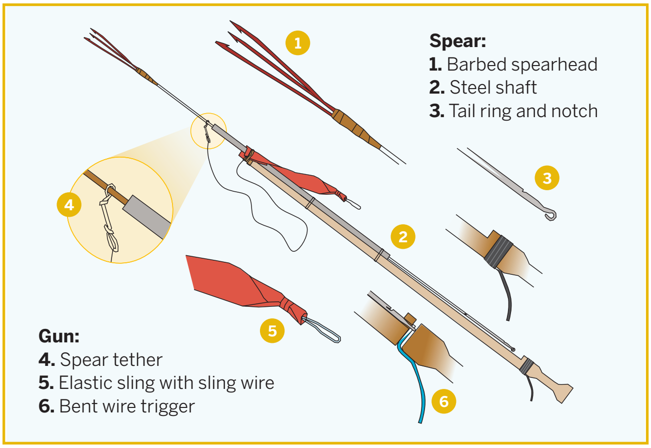


Photograph by Jen Siska

By Tim Anderson

Papuan Speargun

This speargun gets its power from a strip of red rubber.



PAPUAN SPEARGUN: Built in 1978 by Abram Waromi. Still used by his son John Waromi (above) in 2004.

John Waromi lives in Jayapura, Papua, Indonesia. He went to college in Jakarta and traveled the world in a theater troupe before returning home. When he fishes, he uses the speargun his father made, sailing his outrigger canoe out to a fishing spot in the bay.

This speargun gets its power from a strip of red rubber. It came from the inner tube of a giant mining truck at Tembagapura, the "city of copper." The copper mine is hundreds of miles away, across mountains so high they have glaciers despite being near the equator.

Waromi has a cousin who works in the mine. He was driving a giant mining truck in a convoy of three when he saw the other two disappear in a landslide. The other crews were killed and the trucks destroyed. Waromi's cousin would be considered a very distant relative in our Western kinship system, but they belong to a kinship system that would make our cousins into brothers and strangers into cousins. Waromi's got family everywhere, and his speargun has fresh, bright red elastic as a result.

If you see a fisherman with cracked, faded elastic on his speargun, you'll know that his family is not so well connected by the sort of human networks that once brought cowry shells to the high mountains of Papua and fine stone adze heads to the coast.

Before World War II, Jayapura was a collection of villages called Hollandia, with a population of a few thousand. Then hundreds of thousands of American troops moved in for the war in the Pacific.

When they left, they dumped equipment and munitions in the harbor. Those underwater dumps have become something of a hardware store for the locals.

The barbed head of Waromi's spear was made from stainless steel welding rods. The shaft was pulled from the edge of a discarded mattress. The tail is forged into a ring, which the trigger wire fits into. A notch is cut in the shaft near this ring to engage a wire loop tied to the tail of the elastic sling. The spear shaft and the gun are both about 4 feet long.

Tim Anderson (mit.edu/robot) is co-founder of Z Corp. See hundreds more of his projects at instructables.com.

Illustration and photography by Tim Anderson

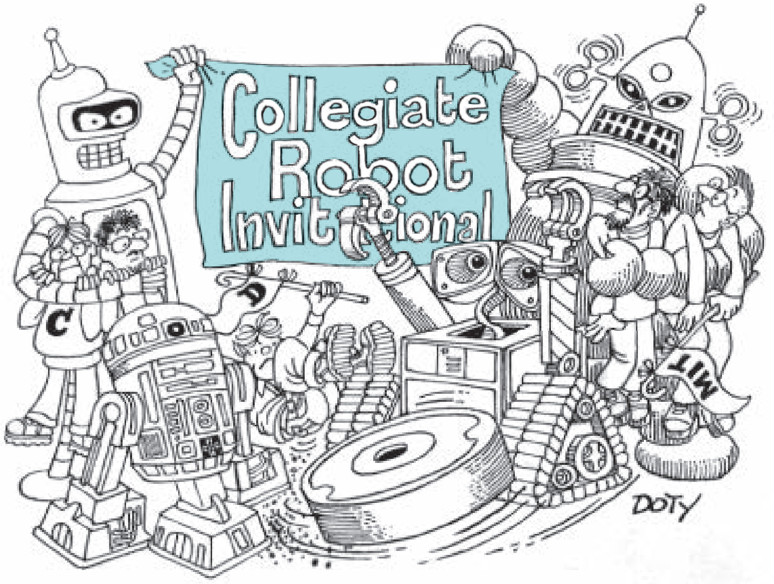
AHA! **Puzzle This** By Michael H. Pryor

MAKE's favorite puzzles. (When you're ready to check your answers, visit makezine.com/19/aha.)

Robot Trouble

Five students at five different colleges were working on their five robots for the Collegiate Robot Invitational the upcoming weekend. On each day in the week before the competition, one student found both a hardware bug and a software bug in their robot.

For each day (Monday to Friday), determine the name of the robot that had problems, the physical problem, the software problem, and the school where the robot broke down.



1. The Dartmouth student discovered his bugs later in the week than the student who broke a gear, and earlier than the one who got the `Out of memory` exception.

2. The student who built the R2-D2 robot discovered his bugs before the student from Rose-Hulman, who found his before the student whose motor burned out.

3. The kid from Cornell found his bugs later than the kid who had the stack overflow, and earlier than the student who built Bender the Robot.

4. The broken gear (which was not one of R2-D2's problems) did not happen to the same robot that had the `Stack overflow` error.

5. The Cornell student did not have an infinite loop in his code. The `Infinite loop` error was found the day before one of the other robots' bearings rusted out.

6. The robot at Rose-Hulman did not have any gear-related issues, nor any stack overflows.

7. Robby the Robot (who did not have an `Out of memory` exception) broke on the day after WALL•E broke.

8. Bender the Robot (who wasn't at Stanford) didn't have any timing belt issues.

9. The robot that had the `Off by 1` error did not have a bent spring.

10. The burned-out motor was not a problem at Stanford or MIT, and the MIT kid did not have an `Out of memory` exception.

11. R2-D2 wasn't at Stanford or MIT.

12. One of the robots was named Roomba. One of the robots had a `Divide by 0` error.

HINTS

Software errors are:
- `Out of memory`
- `Off by 1`
- `Divide by 0`
- `Stack overflow`
- `Infinite loop`

Hardware problems are:
- Gear problems
- Rusted bearings
- Timing belt issues
- Burned-out motor
- Bent spring

Illustration by Roy Doty

Michael Pryor is the co-founder and president of Fog Creek Software. He runs a technical interview site at techinterview.org.

Robot brains, brawn, books, and kits, plus 21st century hand tools, and things to *not* try at home.

TOOLBOX

Torquey Little Tool Kit

Ryobi One+ 18V Cordless Tool Kit

$160 ryobitools.com

With three substantial tools, the Ryobi One+ 18V Cordless Tool Kit is definitely worth the money. I've used the cordless drill time and again for both assembly and disassembly work, and I can tell you from experience that it has enough torque to not only drill out a malfunctioning bike lock, but effortlessly bore an inch farther into the hardened steel around it.

The reciprocating saw is quite nice, especially for handling either wood or metal, as both blades are included. Its only drawback is that the foot surrounding the blade isn't easily adjustable.

Finally, the circular saw has only a 5½" blade, but don't let that fool you: if you don't press hard, you'll extract smoke along with sawdust from your work, as it too delivers surprisingly high torque.

The lithium batteries will hold a good charge, sitting at room temperature, for more than six months and will give you at least a good four hours of work time on a charge. And they're backward-compatible with older Ryobi One+ 18V tools that came with NiCads. About the only thing I'd change about this kit is switching the bulb in the flashlight to an LED.

—Pete Marchetto

Want more? Check out our searchable online database of tips and tools at makezine.com/tnt.
Have a tool worth keeping in your toolbox? Let us know at toolbox@makezine.com.

Military-Grade Awesome

Extra Heavy Duty Screwdriver Set

$30 garrettwade.com

If you believe the ad copy, these are mil-spec screwdrivers that "were standard equipment in all U.S. Army tanks" up to about 20 years ago. I own a set, and it's entirely plausible. These are full-tang, forged-steel, flat-blade screwdrivers that serve equally well in turning screws, prying stuff, and, you know, killing people who try and open your hatch. They're heavy and nigh indestructible, and they have an anomalously sleek, streamlined shape that feels great in your hand and is not bad looking in your boot, either. Regrettably, not available in Phillips. *—Sean Ragan*

Crowbar of the Gods

Titanium Clawbar Nail Puller

$90 stilettotools.com

Titanium crowbars first appeared, at least on my radar, amongst the spoils that flooded Western markets following the collapse of the Soviet Union in 1991. I snagged one around then from a he-man catalog for my Dad's birthday, and although it was pricey, his jaw totally hit the floor when I gave it to him: "I never imagined I could own something like this in my lifetime." He's an engineer, so that's more than just a comment on the price of the gift. He's been using it for more than a decade now and loves it. It's indestructible, rustproof, and amazingly lightweight. It hefts like aluminum, pries like steel. An awesome, awesome tool.

The price of titanium has been on a roller-coaster ride since then, and the stream of cheap Soviet ti-tools has long since dried up. These days, the leader in titanium tool tech is Stiletto Tools of Winton, Calif. Their 12" Titanium Clawbar Nail Puller is a relatively affordable entree to the glories of titanium tools, and features a cool "dimpler" doodad that recesses the wood around a flush nailhead to make it easy to grab onto. Those with deeper pockets may want to spring for their 16" TiBar Titanium Utility Bar, a truly formidable implement of destruction which, like a samurai sword, should probably be offered libations of sake before being taken into battle. *—SR*

Blade Runner

Gerber Artifact

$10 gerber-tools.com

I'm ready to swear that knife sharpening is an urban myth. Everyone's uncle's barber's cousin is an "expert," but no two of them ever agree on a method. I've read books, bought jigs, and interviewed the pros, but I just can't make it work.

So when the first folding utility knives appeared a few years back, I enthusiastically signed on. Now, instead of fretting over resharpening my blade, I can just replace it when it gets dull. Steel is recyclable anyway, so there's no harm done, and the small expense is made up for in time saved.

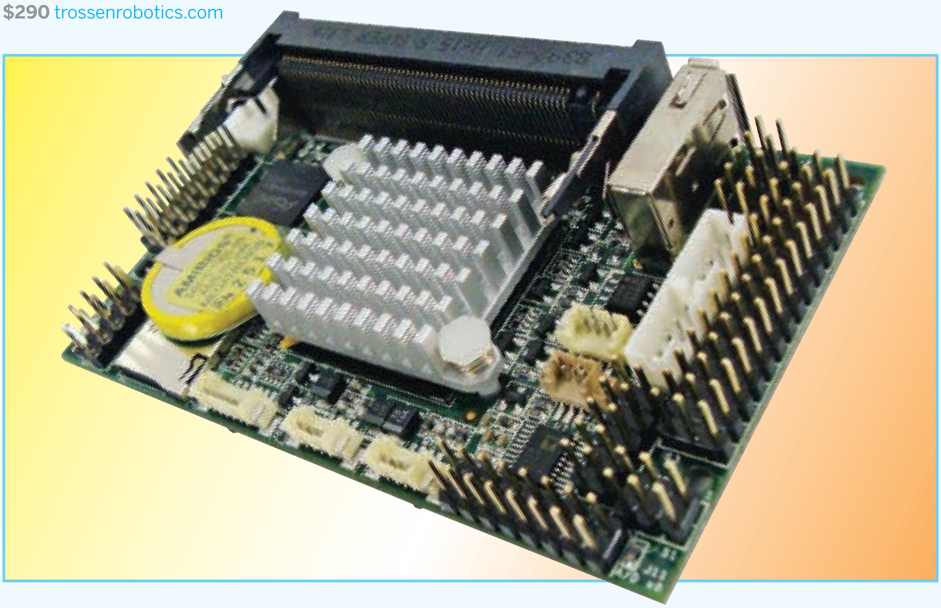
But folding utility knives have their drawbacks. For one, they're big and clunky. They have to be, to provide a sturdy folding frame that encloses a mechanism for interchanging blades. These blade-swapping devices, in turn, are generally either flimsy or fussy — they don't resist pocket wear and/or they use tiny parts that require tools to engage.

Gerber's solution? Shrink the blade! Instead of co-opting the disposable utility razor, their Artifact mounts a folding #11 hobby blade. These are just as common as their larger cousins, and about the same price, but small enough to be safely retained in a compact folding frame by a mechanism that doesn't requires tools. Besides this cleverness, the Artifact incorporates seven other handy implements, including some, like a pry bar, rarely seen in multitools, and all in a package about the size of a pack of gum — and only slightly more expensive.

—SR

Give Your Bot a Big Brain on a Tiny Board

RoBoard RB-100 Starter Kit
$290 trossenrobotics.com



The RoBoard (sold in the United States by Trossen Robotics) is essentially a 1GHz PC-compatible x86 board in a 96mm×56mm ×22mm (3.78"×2.2"×0.85") package. It has 256MB RAM and all the normal ports you'd expect on a laptop: microSD slot, USB, Ethernet, VGA, PS/2, audio, and serial ports.

But it also includes the I/Os found on a microcontroller: I2C and SPI serial, 8-channel analog input, and 40 digital input/output pins. Somewhat uniquely, it also offers hardware support for up to 32 R/C servos. It does all this while drawing only 2.5 watts of power (5V at 500mA).

The RoBoard can run any standard desktop OS that fits in 256MB of RAM and onto the 4GB "disk" of a user-supplied microSD card. At roboard.com, you can find good instruction manuals for installing Windows XP and Linux. You need an external USB floppy and CD-ROM for Windows, or a USB flash drive to install Linux. Installation is about as complex as on a netbook, except that you must supply your own monitor, keyboard, and mouse. I installed the recommended version of Debian Linux without a hitch.

Netbooks like the Eee PC can be considered competitors to the RoBoard. Netbooks run a real OS too and have the added benefits of wi-fi and more memory, but netbooks are still about 10 times larger and don't include all those I/O pins.

Smartphones, like the G1 or iPhone, can work as bot brains, but are even more limited in their physical I/O connectivity. Wi-fi routers running Linux make great robot platforms, but are physically larger and have limited memory and I/O; some I/O issues can be solved by adding an Arduino board, but that increases size and coding complexity.

The RoBoard sits squarely in the middle and solves a lot of problems in a tiny package. Not having built-in wi-fi is a big minus, but can be remedied with a USB wi-fi adapter.

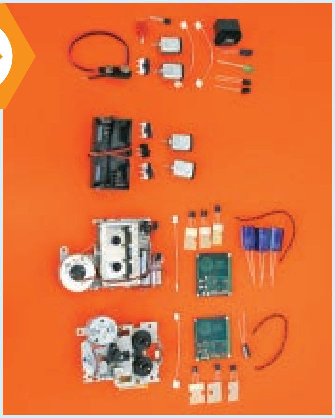
As a robotics hobbyist, I wish the price were a bit lower, but if you need the RoBoard's capabilities, it's well worth the investment.

—Tod E. Kurt

Marc de Vinck shares some of his favorite robot-related products in the Maker Shed.

Bundle of Bot Parts

$70 **Solarbotics**



We've featured a virtual army of little robots in the pages of MAKE, and Solarbotics created a kit bundling all of the harder-to-find electronic components to make four of them. You'll need to source more parts for each bot, but this will get you well on your way. Mousey the Junkbot (Volume 02) is a quirky light-seeking bot housed in an old computer mouse. It scoots fast, crashes, and zips off in the opposite direction. Trimet and Solarroller (Volume 06) are both diurnally active BEAMbots. Watch out as these bots spin and roll around until the sun goes down. And Beetlebot (Volume 12) is a sweet bugbot that navigates obstacles with feelers and switches. No shortage of character in this motley crew!

Co-Robot Kit

$30 **Gakken**

This little robot kit from Gakken is tough! Through some impressive engineering, a single motor is able to power the robot and all of its motions. The Co-Robot walks like he's on a mission, and if he falls over, is able to right himself and continue on. A great kit for introducing kids to the world of kit-making and robotics.

Twitchie Robot Kit

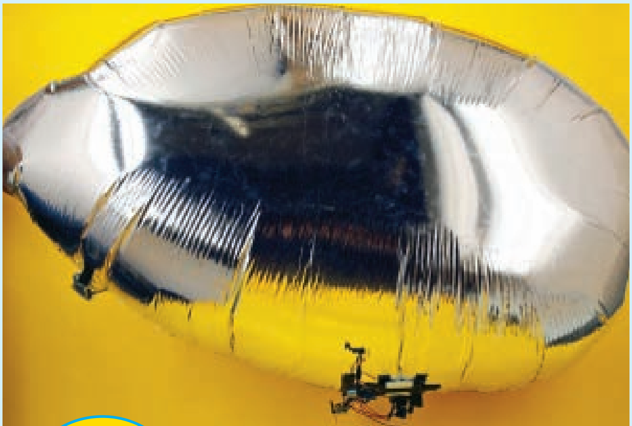
$100 **Teuthis**

The Twitchie kit was designed to bring plushie toys to life. It requires minimal soldering and is designed so that it can be assembled in an unlimited number of configurations. The microcontroller comes preprogrammed, so no coding is required to get it going. If/when you do decide to reprogram, it's easily done to meet your specific twitching needs. Twitchie is a place to get started with robots and Arduino programming, for both kids and adults.

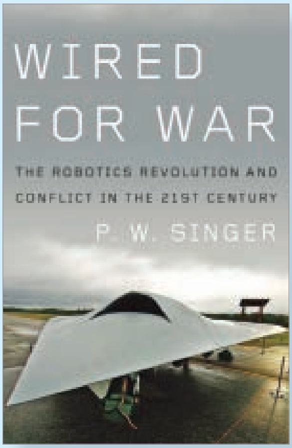
Blimpduino Kit

$90 **DIY Drones**

The Blimpduino kit is a very low-cost, open source, autonomous blimp created by Chris Anderson of *Wired* magazine and Jordi Muñoz of DIY Drones. The kit consists of a blimp envelope and Arduino-based blimp controller board with onboard infrared and ultrasonic sensors for navigation and altitude control, along with an interface for optional R/C mode. The gondola has two vectoring (tilting) thrusters that guide the blimp based on the position of the included ground-based infrared beacon. A great way to experiment with autonomous aerial robotics without spending a fortune. (Read more about the Blimpduino on page 52.)



There are many more robots, kits, and components in the Maker Shed, and more are added every week. Stop by makershed.com and check them out.



Fought by Bot

Wired for War: The Robotics Revolution and Conflict in the 21st Century
by P.W. Singer $30 **Penguin Press**

Should a robot kill people? Is it cowardly, or evil, to send a robot army against human beings? Are robotic "wars of choice" too tempting? Science fiction has explored all these questions, from Asimov and Clarke to movie terminators, robocops, and droid legions. But now they're being asked in real-world policy circles.

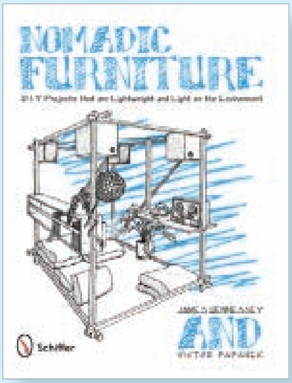
P.W. Singer, a young Brookings Institution war analyst, is a highly entertaining writer whose latest book explores the rapid rise of war robots, how they'll be used in the future, and how they're already affecting the moral calculus of war.

How rapid? From just a few UAVs in 2003, the U.S. robot force has grown to more than 7,000 aerial drones and 12,000 ground bots. Predator drones are launching Hellfire missiles at people in Afghanistan, piloted by guys in Nevada. iRobot makes war bots alongside Roombas, and Pentagon planners envision Navy "motherships" coordinating robot swarms. More than 40 countries are working on military robotics, from two-legged war "mechas" in Japan, to crude DIY bots built by Iraqi insurgents.

War in the future will increasingly be fought by bot. For now, people still call the actual shots, but human operators are increasingly remote from the fight, and Singer predicts the day's not far off when robots will make their own decisions about which targets to strike. And with robots to do the fighting and dying, he warns, maybe voters and legislators will no longer bother to rein in warlike leaders. "Our new machines offer incredible, near science fiction-like capabilities," Singer writes, "but they also bring in terrible new quandaries."

—Keith Hammond

+ More by P.W. Singer at pwsinger.com/articles.html



DIY Furniture Classic

Nomadic Furniture **by James Hennessey and Victor Papanek**
$30 **Schiffer Publishing**

Before there was Ikea and "Ikea Hacking," there was this book. Actually, it was two books, *Nomadic Furniture 1* and *Nomadic Furniture 2*, released in the 1970s. As a young hippie delving deeply into the *Whole Earth Catalog*, Bucky Fuller, "whole systems," and sustainable living, I found them to be a revelation. In an early example of "open source," the authors, both architects, designed dozens of chairs, tables, lamps, shelves, and beds, and drew the plans in these books.

With so many people now familiar with the "stick furniture" of Swedish retailers, and with a newfound enthusiasm for reuse, recycling, and making your own, it was a smart move for Schiffer to combine these classics on lightweight, portable, eco-friendly furniture into one volume. While most of the designs are perennial and functional, some are now wonderful 70s kitsch. And the section on 70s stereo gear is a great trip down Memorex lane (Revox Mark III reel-to-reel, anybody?).

—Gareth Branwyn

« Don't Try This at Home?

Mad Science **by Theodore Gray**
$25 Black Dog & Leventhal Publishers

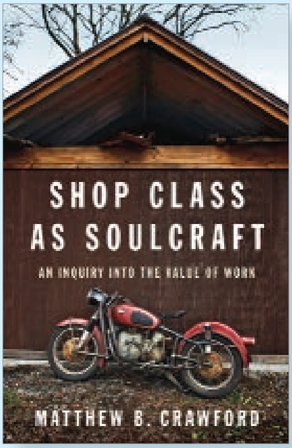
In the introduction to *Mad Science: Experiments You Can Do at Home — But Probably Shouldn't*, Theo Gray writes: "It makes me cringe when I see warnings to wear gloves and safety glasses while working with baking soda. It's called crying wolf, and it's deeply irresponsible, because it makes it that much harder to get through to people about real dangers."

Reviewing Gray's book, I'm faced with a similar problem: readers today are so bombarded with superlatives and exclamation points, that they're desensitized to authentic praise. So I'll put it this way:

If you've ever thrilled to a chemistry demo, *Mad Science* will bring you tremendous joy. If you've ever whiled away an evening (or eight) figuring out how hard it'd be to construct your own 3MeV linear accelerator for making Lichtenberg figures, you may be unable to put this thing down. My review copy is dogeared at nearly half of the 50 experiments included. In the week since I received it, I've already been to the shop more than once to fan some spark that was struck in its impressive pages.

Be warned: the subtitle's not just to be funny. Many of these experiments involve flammables, incandescent temperatures, and/or highly reactive ingredients. Some of this definitely should not be tried at home. On the other hand, after reading, many will count as experiments you don't need to try: beautiful photos on oversized pages give you a great idea of what it'd actually look like if you were to, say, direct a stream of chlorine gas into a bowl full of metallic sodium.

But there's plenty of safer fare here, too. I, for one, can't wait to try making ice cream with liquid nitrogen. And the information on home metal casting has me itching to dig out my old *Star Wars* figures to pour out that army of stormtroopers I've always wanted. Gray's done an excellent job of conveying the sense of wide-eyed wonder that goes along with amateur science, and ultimately, that may be the book's greatest accomplishment. *—SR*



« Hand to Mind

Shop Class as Soulcraft: An Inquiry into the Value of Work
by Matthew B. Crawford $26 Penguin Press

Industrial arts classes are closing in schools across the country (and the rest of the world). One reason is that they're expensive — a shop instructor can't teach 50 students at once. Another is that skilled-trades workers usually earn less than knowledge workers, so schools are pressured to replace lathes and drill presses with PCs.

This is, to Matthew B. Crawford's mind, a tragedy. In his book *Shop Class as Soulcraft: An Inquiry into the Value of Work*, Crawford argues that skilled labor, such as carpentry, plumbing, and car repair, both challenges the intellect and nourishes the soul.

He should know. A former electrician, Crawford owns a motorcycle repair shop, and his accounts of troubleshooting broken bikes and fixing them read like an adventure into the unknown. This book has the potential to become a 21st-century manifesto for a more meaningful way of living. *—Mark Frauenfelder*

As chosen by Steve Norris, avid bot builder and *Robot* magazine writer.

A4WD1 Rover Kit

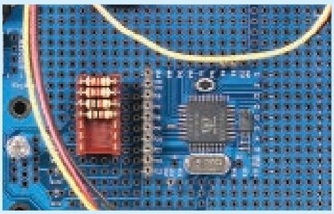
The all-metal A4WD1 Rover kit is a versatile wheeled platform. This rover has four 5" R/C tires, each with a 7.2V motor or, for higher torque, a 12V motor. There's plenty of room for batteries and electronics, but if you run out of space, additional decks can be stacked on the top for easy expansion (as seen here, including the Parallax Ping sensor, reviewed below). lynxmotion.com

ServoCity Linear Actuators

Add mechanical magic to your bot by using these linear actuators from ServoCity. Famous robots such as my RoboStool and RoboCam implement their *Transformers*-like features thanks to these actuators. They come in a range of sizes, from 2" to 12", and can extend and retract at about ½" per second. They all use a 12V motor and have a built-in 10K potentiometer that can be used to determine position. servocity.com

Parallax Ping Ultrasonic Sensor

Like people, robots should not go around bumping into stuff. The Parallax Ping sensor can be the foundation for any obstacle-avoidance system. Using an ultrasonic pulse, the unit detects and accurately determines the distance to a target. Using one shared I/O pin, the Ping is easy to interface with the BASIC Stamp and other microcontrollers. parallax.com



Parallax Propeller Chip

Designing and building robots is all about concurrent operations, and Parallax's Propeller chip supports concurrent processing by providing eight microcontrollers called "cogs" built into one chip. Each cog has its own memory, in addition to the main 32K of RAM that's shared by all eight. The cogs can work cooperatively or individually on simultaneous tasks while sharing resources through a common hub. The Propeller can be programmed in high-level languages such as C, and in a specially designed concurrency language called Spin. parallax.com

Sherline Tabletop Lathe and Mill

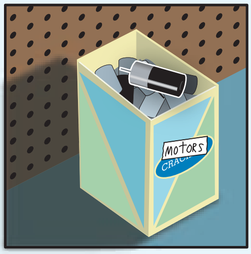
Scratch-building a robot? A Sherline tabletop lathe or mill may be your ticket. A mill, partnered up with the proper accessories, is capable of machining almost any shape you desire, out of most materials used in robot fabrication. And that includes titanium. Lathes work best for cutting down material diameters, facing cuts, or even threading materials. These are serious tools for the serious hobbyist. sherline.com

Microcontroller Tutorial Kit

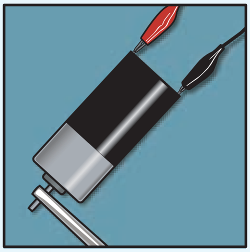
Parallax's microcontroller programming tutorial is a great starting place for any budding bot builder. It introduces the BASIC Stamp module and the PBASIC programming language. The kit also includes parts for building simple and advanced electronic circuits using LEDs, a "tact" switch, push buttons, and a servo. It's also a starting point and excellent background reference for Parallax's more advanced tutorials. parallax.com

Tricks of the Trade By Tim Lillis

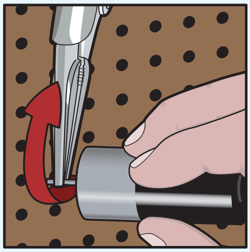
Get your motors runnin'!



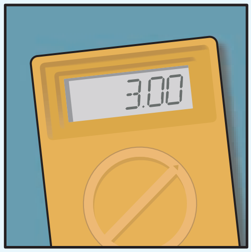
Have a bunch of motors in your shop but don't know their voltage ratings? Use this trick from Dave Hrynkiw at solarbotics.com to get organized!



First, attach a pair of vise-grip pliers to the output shaft. Then hook the motor terminals up to a voltmeter.



Holding the motor, spin the output shaft reasonably fast until you feel a decent load. (Not too hard — don't break it!)



As you spin the motor, you'll see the approximate voltage range intended for that motor! This trick works best with gearmotors.

Have a trick of the trade? Send it to tricks@makezine.com.

Robot Media Comes of Age

***Robot* magazine** botmag.com
$25/6 issues

***Servo* magazine** servomagazine.com
$25/12 issues

Back in the radio days of hobby robotics, magazines about robots were almost nonexistent. There were a few robot hobby club newsletters and that was about it. But today, there are two very juicy magazines whose contents complement each other very well.

Robot magazine is published by Maplegate Media, maker of hobby mags such as *RC Driver* and *Fly RC*. As such, it's a bit more focused on more commercial, out-of-box bots. *Servo* is a spinoff of the venerable *Nuts & Volts* and tends to be more about ... well ... nuts and volts, geekier and more geared toward scratch-built robotics. Put the two together and you get a pretty high-bandwidth look at hobby, educational, and consumer robotics. *—GB*

Gareth Branwyn is a senior editor of MAKE and the cat herder at Make: Online.

Marc de Vinck is the product curator for the Maker Shed, a member of the MAKE Technical Advisory Board, and an author for Make: Online.

Mark Frauenfelder is MAKE's editor-in-chief and founder of boingboing.net.

Keith Hammond, for one, welcomes our new robot overlords. He's copy chief at MAKE.

Tim Lillis shows you how to use stuff better than you knew you could.

Tod E. Kurt is creator of the BlinkM Smart LED and co-founder of ThingM.

Pete Marchetto considers himself a physicist-at-large, and when he's not making stuff, he's looking at birds and enjoying the great outdoors.

Steve Norris (norrislabs.com) is an active robot builder and regular contributor to *Robot* magazine (botmag.com).

Sean Michael Ragan's ancestors have been using tools for 5,000 generations. Also he went to college 'n' stuff.

Have you used something worth keeping in your toolbox? Let us know at toolbox@makezine.com.

By Donald Simanek

Golden Star Origami

The five-pointed "golden star" is widely used around the world in flags, heraldry, coats of arms, and other decorations. It's been used in American flags of many designs from the earliest days of our republic.

» Historical legend tells us that seamstress Betsy Ross was visited in 1776 by George Washington, Robert Morris, and George Ross, who asked her to make an American flag conforming to a resolution of the Continental Congress.

Washington's design had 13 alternating stripes of white and red, and 13 six-pointed stars on a field of blue. Betsy suggested five-pointed stars instead. When someone wondered whether five-pointed stars would be more difficult to make, Betsy showed how fabric could be cleverly folded to allow a five-pointed star to be made with just one cut of the scissors.

It's a pretty story, but like many fables of our early history, it's probably a myth. Contemporary documentation of it is totally lacking. Betsy's grandson first related the story in 1870, nearly a century after the fact, admitting that he had no confirmation other than stories passed down in the family.

The story quickly proliferated, being published in *Harper's New Monthly Magazine* in 1873, finding its way into other publications and even into textbooks, persisting even now. And the Betsy Ross House in Philadelphia is the second-most-visited historic site there, but there's no hard evidence that she ever lived in it.

We'll leave historians to sort all that out. You can find out more about the flag myth at makezine.com/go/flag. What catches my interest is the method of folding cloth to obtain a five-pointed star with a single scissors cut. It's the one believable detail in this story. Creating five-fold symmetric figures is a challenge in Euclidean geometry, and with paper folding, too. But a method is well known to quilters and seamstresses and was surely known to flag makers of colonial times and earlier.

Here are the instructions to make a star template using a sheet of thin 8½"×11" paper:

Star Construction

★ Fold the paper in half, to 8½"×5½", with the fold at the top. Then fold the paper in half again to make a temporary crease to locate point C at the midpoint of the right edge. This crease is shown as a dotted line in Figure A.

★ Mark the upper right corner "A" so you won't lose track of it. Mark the upper left corner "B."

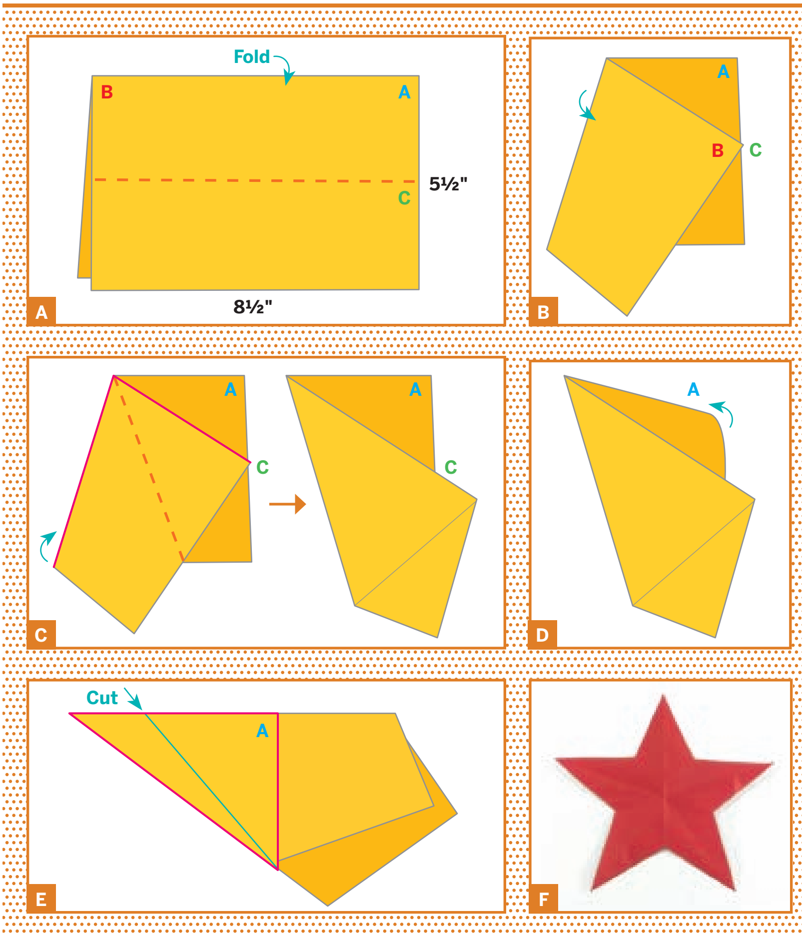
★ Bring corner B over to point C, just at the midpoint of the right edge of the paper, on the crease you made earlier. The left portion of the top edge of the paper folds over, making an angle along the solid line to point C. This angle is the foundation of the construction (Figure B).

The angle is approximately 35.85584°. This is smaller than 36°— one tenth of a full circle — but very close to what we need to define the polygon vertices that are the basis of a five-pointed star. This is an approximate construction, not a strictly Euclidean construction. (Euclidian constructions don't use measuring tools. This construction starts with a measured rectangle of paper.)

★ Fold the lower left edge up to lie along the slanted fold that passes through point C (Figure C).

★ Grabbing hold of point A, fold the paper backward along the diagonal so that all edges coincide. This will make an angle of approximately 36° (Figure D).

★ Now turn the whole thing over. Notice that there's a right triangle on the top of the folded stack of paper. Draw a line — starting about ⅓ of the way in along the long (top) side — to the lower corner of the triangle (Figure E). Use suitably heavy scissors to cut the whole stack along the line and unfold the paper.



MAKE A STAR WITH ONE CUT

Fig. A: Fold an 8½"×11" sheet of paper in half. Fold in half again to make a temporary crease lengthwise. Mark points A, B, and C.

Fig. B: Bring corner B over to point C.

Fig. C: Fold the lower left edge up to lie along the slanted fold (connect the 2 pink edges).

Fig. D: Fold corner A backward so that all edges coincide.

Fig. E: Flip the paper over. On the topmost triangle (outlined in pink), draw a line starting ⅓ of the way in from the narrow point, down to the lower point. Cut along the line. Unfold and discard the outside extra paper.

Fig. F: The payoff!

You should now have a near-perfect five-pointed star like the one shown in Figure F. Other variations can be obtained by tilting the cut line differently. Cut from the lower corner to the midpoint of the opposite side and you get a "fat" star. Experiment for other variations. The remainder of the sheet of paper can be used as a stencil to decorate your house or automobile with painted stars.

Afterthoughts

You may wonder whether 8½"×11" paper was common in 1776. If it wasn't, this would suggest that the Betsy Ross flag story is a fabrication. (I coudn't resist that one.) But yes, 8½"×11" paper was available then. That size goes back to Europe in 1600, the result of a 17"×22" sheet cut into four pieces. Not until the time of the first World War did 8½"×11" paper become standard for business in the United States. I've tried similar constructions starting with sheets of other sizes, but these usually result in awkward unanticipated difficulties.

The story of the invention of this star construction method remains to be told. Who was the clever person who discovered it? I shall resist idle speculation about how the size of paper necessary for this construction might mystically relate to the Golden Mean or to the Fibonacci sequence.

Congress did not specify how the stars were to be arranged. Many flags of that time and earlier had "stars and stripes," with the stars arranged in various ways. Flags with stars in a circle were rare. A painting by Charles H. Weisgerber, made in 1870, shows Betsy Ross stitching a flag with stars in a circle while Washington, Morris, and George Ross look on.

That suggests another mystery. What trick of geometry, or origami, would you need in order to arrange 13 stars perfectly spaced around a circle?

Donald Simanek is an emeritus professor of physics at Lock Haven University of Pennsylvania. He writes about science, pseudoscience, and humor at www.lhup.edu/~dsimanek.

Illustrations by Katie Wilson; photograph by Becky Stern

By William Gurstelle

Rudolf Diesel and the Fire Piston

Welcome to the first installment of Remaking History, where I'll trace the connections between the science and history of an experiment or invention, and show you how to re-create it as a project for your home workshop. If you have suggestions for a Remaking History column, I'd love to hear them.

—*William Gurstelle, remakinghistory@makezine.com*

» Carl von Linde was dead tired. The eminent engineer, considered the father of the modern refrigerator, had just returned to his home in Germany from a lecture tour that took him to, among other places, Malaysia. This being the late 19th century, the voyage had taken months. Von Linde had seen and learned much during his excursion to Southeast Asia, and as a faculty member of the prestigious Munich Technical University, he was obligated to deliver a presentation on the results and findings of his trip to students and faculty.

During his lecture, the fatigued Herr Doktor felt the need for a nicotine hit. He paused and withdrew from his pocket a small wooden cylinder and plunger, which he called *ein Feuerkoben*. The small device was a gift from the people he had met on Penang Island in the Strait of Malacca. The indigenous people of the region used it to start fires. A person experienced in the use of the Feuerkoben, or fire piston, could reliably provide hot, glowing embers anytime they were needed, even under the humid conditions of the rain forest.

At the lectern, von Linde slapped the plunger down and the tinder inside ignited. He plucked out a glowing ember and lit his cigarette with it. It was a neat gesture; to the audience, it looked like he had produced fire from nothing at all — no match, no flint. The fire had magically appeared from the bottom of an empty, hollowed-out tube.

The concept was not lost on audience member Rudolf Diesel, who was one of Professor von Linde's most promising students. Diesel had been experimenting with the recently invented internal combustion engine and was growing frustrated with the spark-ignition engine's inherent low efficiency. When von Linde lit that cigarette, a question jumped into Diesel's head: Could the same thermodynamic process that ignited the tinder in the bottom of the fire piston also ignite fuel in an internal combustion engine? If so, perhaps here was a way to significantly improve the engine's efficiency. And as history proved, it was indeed.

Unlike typical gasoline engines, the eponymous and now ubiquitous diesel engine has no spark plug or carburetor. Instead, the diesel engine works by compressing fuel under very high pressures. When the fuel-air mixture in the cylinder compresses, it also gets very hot. In fact, it quickly exceeds the flash temperature of the fuel and ignites it. The compressed gas expands violently upon ignition and pushes the compressing piston away with enough force to easily turn a drivetrain.

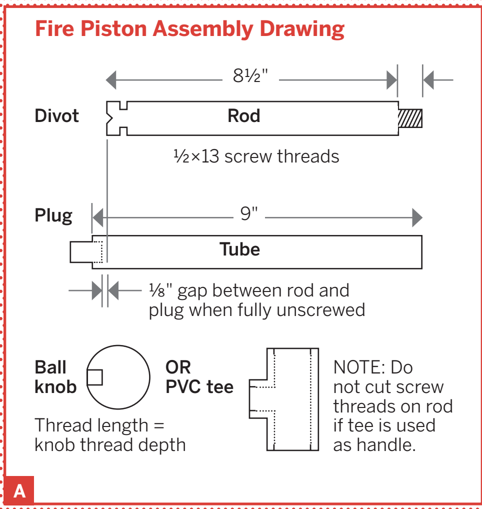
Scientists had known for 100 years that compressing a gas in a closed, insulated space causes it to get hot. In 1809, French scientist Joseph Gay-Lussac conducted experiments that proved the temperature of a fixed mass and volume of a gas is directly proportional to its pressure.

But it fell to Diesel to figure out how to use this knowledge to make a high-efficiency engine that could work with no need for a spark. Diesel published a paper in 1893 outlining his ideas for a spark-free, compression-ignition engine. In 1897, he built the world's first working compression-ignition internal combustion engine.

Was von Linde's fire piston the true antecedent of the Mack truck engine? Well, accounts vary, but one thing is certain: the fire piston is not only fun to make and use, it's scientifically interesting and historically significant. Here's how to make your own.

MATERIALS AND TOOLS
Available at smallparts.com or mcmaster.com

- Rubber O-rings, ¼"ID×7⁄16"OD×3⁄32" wide (2)
- Clear polycarbonate or acrylic rod, ½" diameter, cut into 2 lengths: 12" and 1¼"
- Clear polycarbonate or acrylic tube, ½"ID×⅝"OD×9½" long
- Ball knob, 1⅝" wide, with ½-13 female thread ⅝" deep
- Tap and die set to cut a thread matching the ball knob
- PVC tee fitting, ½"×½"×½" (optional) instead of the ball knob and tap and die set
- Cyanoacrylate or methylene chloride-based adhesive
- Petroleum jelly
- Epoxy glue
- Lathe, table saw, or handsaw
- Sandpaper
- Plastic polish and steel wool
- Drill and ¼" bit



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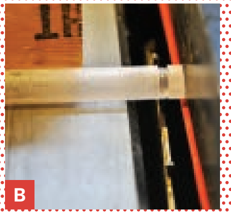
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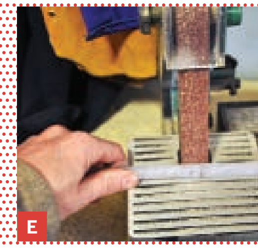
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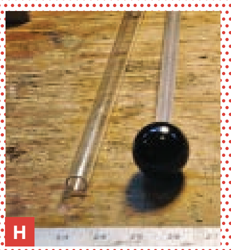
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I

Photography by William Gurstelle

Making a Fire Piston

1. Cut the O-ring groove.

Referring to the assembly diagram (Figure A), cut the groove for the O-ring about ¼" from the end of the rod. The depth of the groove should be just slightly less than the width of the O-ring. If the groove is deeper, the O-ring won't seal against the tube properly. If the groove is too shallow, you won't be able to insert the rod into the tube.

The best way to cut the groove is with a lathe. But if you don't have one, then what? Improvise! I used a table saw to cut the groove, and after a bit of trial and error, it worked fine. Raise the saw blade so the height of the blade protruding over the table equals the diameter of your O-ring, minus 1–2 hundredths of an inch. Carefully spin the rod as it contacts the blade to make an even slot (Figure B). (You might not succeed on your initial tries. The rod is long enough so you can cut off mistakes and try again.)

2. Glue the plug.

Using cyanoacrylate or methylene chloride-based adhesive, glue the short rod into an open end of the tube (Figure C). It's very important to make this end airtight. Glue it well, and rotate the plug in the tube to distribute the glue.

3. Install the handle.

Use a die to cut a ½-13 thread on the other end of the rod (Figure D). Screw the ball knob onto the thread. Alternatively, instead of using a ball knob, you can glue the rod into the middle hole of a ½" PVC tee fitting for a handle. If you do this, you won't need a die.

4. Fit the piston.

Slide the rod into the tube and check the fit. Use a sanding belt or sandpaper, steel wool, and polish to make a close but free-sliding fit between rod and tube (Figure E, previous page). Cut the rod to a length of about 9½", but measure it carefully first: optimally, there should be about ⅛" of space separating the end of the rod from the plug when the rod's fully inserted.

5. Install the O-ring.

Depending on the width of the slot you cut and the shape of your O-ring, 1 or 2 rings will fit in the slot (Figure F).

6. Drill the "divot."

Drill a ¼" hole ⅛" deep, centered in the end of the rod (Figure G). Your fire piston is now complete (Figure H).

7. Test for air leaks.

Smear petroleum jelly on the O-ring and carefully insert the rod into the tube, working the O-ring past the edge of the tube. Press the piston down to the bottom of the cylinder. If you've done everything correctly, the piston will smoothly and easily pop back up, nearly to the top, when you release it.

If you press on the piston and it just stays in the tube, then the fire piston won't work. If this happens:

» Check for leaks in the plug by spraying the end with soapy water and looking for bubbles when you compress the piston. Seal any leaks.

» Improve the sliding fit by adjusting the depth of the O-ring groove and/or repolishing the piston.

8. Load and fire!

Place a pinch of flammable material in the divot at the end of the rod. The best material is charcloth (see sidebar for instructions on making charcloth).

Smear more petroleum jelly on the O-ring, then carefully insert the piston, working the O-ring past the opening. Place the plug end of the fire piston on a hard surface. Quickly and firmly press down on the knob. You'll see a bright flash in the bottom of the fire piston. Carefully remove the piston from the tube and blow on the glowing charcloth in the divot (Figure I, previous page).

You can now use the smoldering ember to start a larger fire.

William Gurstelle is a contributing editor of MAKE magazine.

Making Charcloth

What's charcloth? Basically, it's cotton cloth that's been roasted to blackness at high temperature but in the absence of air, the way wood is roasted to make charcoal. The wonderful thing about charcloth is that it's very easy to ignite with just a small spark. Charcloth doesn't really burst into flame easily, but it doesn't take much for it to catch fire and smolder, making it just right for starting something else on fire, like tinder or even a cigar.

1. Punch a small hole in the top of an airtight metal container such as a candy tin (Figure J).

2. Place some 100% cotton cloth in the tin (Figure K) and replace the top.

3. Go outside and place the container on a handful of hot charcoal briquettes (Figure L). Almost immediately, the cloth inside will start to roast, and white smoke will pour out of the hole. After several minutes, the smoke volume will decrease or stop, signaling that the charcloth is done.

4. Remove the tin and let it cool. Once it has cooled, you can remove the top and take out the charcloth.

J

K

L

Jan	Feb	Mar
Apr	May	Jun
July	Aug	Sept
Oct	Nov	Dec

MAKER'S CALENDAR

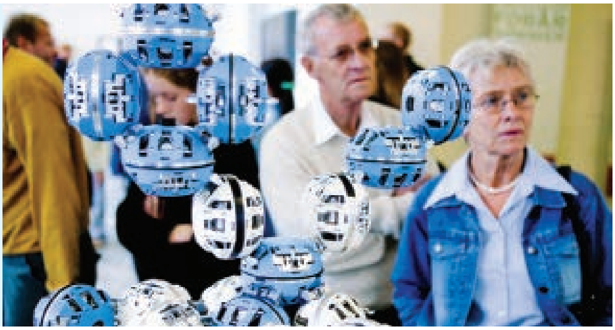
Compiled by William Gurstelle

Our favorite events from around the world.

RoboDays

Sept. 10–12, Odense, Denmark

More than 20,000 people visit RoboDays to interact with playful, instructive, and interactive robots from all over the world. From singing robotic flowers to Blubber Bots (*see MAKE, Volume 12*), RoboDays has something for everybody. robodays.dk



›› SEPTEMBER

Dragon*Con

Sept. 4–7, Atlanta, Ga.

The largest multimedia, popular culture convention in the USA focusing on geek life! Programs include science fiction, fantasy, gaming, computers, robotics, and space science. dragoncon.org

Gas Engine and Antique Reproduction Show

Sept. 19–20, Portland, Ore.

GEARS caters to model engineers and home machinists. Scale-model steamships, engines, and other handmade mechanical creations are displayed and explained. oregongears.org

Red Bull Soapbox Race

Sept. 26, Los Angeles

Outrageous, human-powered soapbox dream machines compete against the clock. redbullsoapboxusa.com

Working Waterfront Festival

Sept. 26–27, New Bedford, Mass.

America's largest commercial fishing port invites visitors to explore boats, mend nets, and watch cooking demonstrations. workingwaterfrontfestival.org

›› OCTOBER

BALLS 18

Oct. 2–4, Black Rock Desert, Nev.

Watch the best and brightest in the world of amateur rocketry demonstrate their ability to build and launch the largest nonprofessional rockets seen anywhere. balls18.com

Science Days

Oct. 15–17, Rust, Germany

Take part in workshops, hands-on experiments, science shows, and more. This year's focus is on space travel and climate change. science-days.de/sdays

California Hot Rod Reunion

Oct. 16–18, Bakersfield, Calif.

Makers of an automotive bent will love CHRR, featuring hundreds of street rods, custom, and muscle cars. There's also a swap meet, a Manufacturers Midway, and "lots of celebrities." museum.nhra.com

Bridge Day Festival

Oct. 17, Fayetteville, W. Va.

Watch expert rappellers and parachutists jump off the 876-foot-high New River Gorge Bridge. Ride the zip line 700 feet down to the road below. officialbridgeday.com

›› NOVEMBER

Electronic Music Midwest

Nov. 5–7, Kansas City, Kan.

Composers from around the world visit the EMM Festival to share their music. Electronic music artists will perform short concerts representing a wide variety of music and media. emmfestival.org

Aviation Nation

Nov. 14–15, Las Vegas

The official air show of the U.S. Air Force, this huge event at Nellis AFB is an unconstrained celebration of aviation technology. Flying exhibits include the Thunderbirds air demonstration squadron and the top-of-the-line F-22 Raptor fighter plane. aviationnation.org

IMPORTANT: All times, dates, locations, and events are subject to change. Verify all information before making plans to attend.

Know an event that should be included? Send it to events@makezine.com*. Sorry, it's not possible to list all submitted events in the magazine, but they will be listed online.*

If you attend one of these events, please tell us about it at forums.makezine.com.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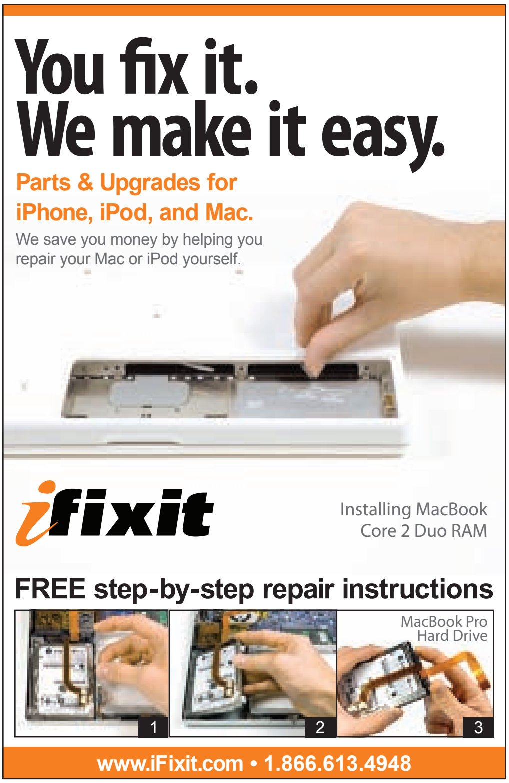
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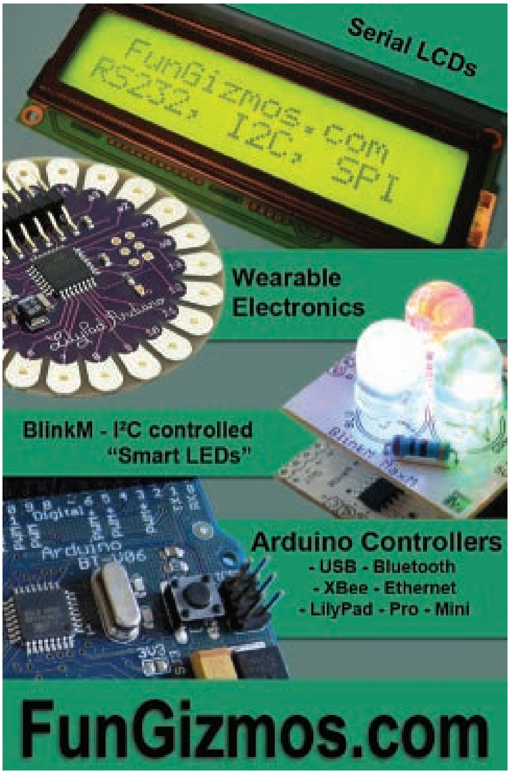

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MAKE MONEY

Eyeglasses

By Tom Parker

Sometimes it costs more to buy it than to make it from the money itself.

$89.95

Single-vision glasses to correct myopia, from optician.

⬆ $1.00

Pinhole glasses made from two half-dollar coins, plus a piece of salvaged brass rod.

Photograph by Tom Parker

The ElliptiGO Glide Bike

By Brent Teal

Photography by Bryan Pate (main) and Marty Sconduto (inset)

When my friend Bryan Pate asked if I could build him an elliptical trainer he could ride outdoors like a bike, as a substitute for running, I was surprised he couldn't buy it. Once I was convinced that it didn't exist commercially, I set about designing one. After extensive 3D modeling, finite element analysis, and many design iterations, the ElliptiGO was born.

Having an adequate stride length was one of the critical aspects of achieving a fun, high-performance, non-impact running experience outside. To facilitate a long stride while minimizing overall bike length, I used an offset slider crank mechanism, with the crank pivot located behind the rear wheel, for the rider-to-drivetrain interface. I leveraged off-the-shelf bicycle parts when possible, including the 8-speed internally geared hub, which provides a great riding experience whether climbing or flying downhill.

I built the ElliptiGO in my garage in about six months. I fabricated everything on the bike myself, including bending the tubes, brazing the frame, and machining all the other custom components. I designed the frame to create a smooth, elegant, sweeping line that connects the bike's functional points without interfering with the rider. I chose fillet-brazed 4130 chromoly steel tubing for the frame because it's strong, doesn't require post-weld heat treatments, and has an easier learning curve compared to welding. To minimize the frame's weight I chose small-diameter, thin-walled tubing and got sufficient stiffness with a sweeping truss design.

One of the toughest parts was creating the two large radiuses out of plane bends in each of the four main structural tubes. The technique that finally worked involved packing sand in the tubes to prevent crimping and using a plywood fixture to get the target bend radius and angle while maintaining the proper phase angle between the two bend planes.

We are very pleased with the performance of this prototype. Bryan has put more than 1,000 miles on it, including a 50-mile ride where he averaged over 15mph, finishing in 3 hours and 16 minutes.

Now, we're moving to production with a professionally built prototype. We're currently taking deposits and expect to deliver bikes by the end of the year.

ElliptiGO video and news at elliptigo.com

Brent Teal is a mechanical engineer and ultra-marathoner who lives near San Diego, Calif.

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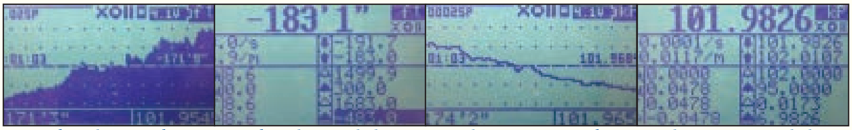
The Next Generation Is Here!

The response to the UP24 was incredible! Customers from professional land surveyors, meteorologists, scientists, pilots and hikers to the curious hobbyist were overwhelmed with its sensitivity and accuracy. Reading realtime elevation to a third of an inch blew their minds! Even with this response we considered it a challenge to make it even better... and we sure did! Introducing the next generation UP24B!

Now you can charge the internal Li-Ion power cell from either an external source of 6VDC to 30VDC or a standard 5VDC USB connection from a PC, laptop, or USB charger! Charging status and battery condition displays are also provided. Next we added a "MARK" feature. This allows storing a single data point reading when YOU want instead of blindly storing readings at the selected sample rate. A simple dry or electronic closure is all you need to set a mark or start point.. Each mark you add creates a new data block. Hi-res atmosphere changes to elevation changes less than a third of an inch, don't even scratch the surface or specs. Visit www.ramseykits.com for complete info and applications.



Elevation Graph | *Elevation Statistics* | *Air Pressure Graph* | *Air Pressure Statistics*

UP24B — High Resolution Elevation/Air Pressure Sensor Kit — $239.95

Retro Nixie Tube Clock

One of the neatest retro clocks available today! Nixie Tubes made their debut in 1954 and we brought them back in 2008! Brilliant 12/24 hour .7" orange display, soft fade, and more. Hand crafted teak and maple base!

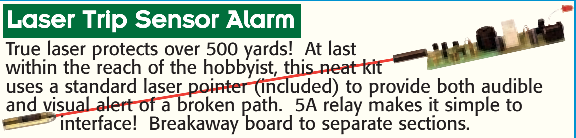
IN14TM — Nixie Tube Teak Maple Clock Kit — $329.95

CarChip Pro OBDII Logger

Here go the gas prices again, up every day, just in time for summer driving! Maximize your vehicle's efficiency and save a lot of gas! Monitors the last 300 hrs of driving, showing you everything you ever wanted to know! Even resets engine lights! Assembled.

8226 — CarChip Pro OBDII Data Logger — $99.95

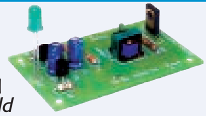
Laser Trip Sensor Alarm



True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1 — Laser Trip Sensor Alarm Kit — $29.95

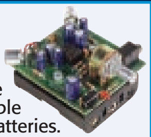
Tickle-Stick Shocker



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, *"Hey, I told you not to touch it!"* Runs on 3-6 VDC.

TS4 — Tickle Stick Kit — $12.95

Stereo Ear Super Amplifier



Ultra high gain amp boosts audio 50 times and it does it in stereo with its dual directional stereo microphones! Just plug in your standard earphone or headset and point towards the source. Incredible gain and perfect stereo separation! Req. 3 AAA batteries.

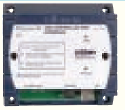
MK136 — Stereo Ear Audio Amplifier Kit — $9.95

Broadband RF Preamplifier

Got the DTV blues? Does the new UHF signal just not make it to your house? Are you located smack in the middle of an RF lobe? Our proven PR2 provides over 25dB of gain with a 50-75 ohm input impedance. Great fix for DTV! Assembled.

PR2 — Broadband Preamp, Asmb & Tested — $69.95

USB Controlled DMX Interface



The mystery of professional stage lighting solved! It's called DMX,, and it provides up to 512 channels of control over a daisy chained XLR audio cable! Control lights, lasers, fog machines, or any other effect with DMX control from your laptop! USB controlled.

K8062 — USB Controlled DMX Interface Kit — $62.95

Xenon Tube Strobe Light

Create amazing effects with an authentic Xenon tube strobe light! Creates a super bright white FLASH with a variable speed of 2 to 20 flashes second. Just connect 110VAC and and you have a complete strobe light!

K5300 — Xenon Tube Strobe Light Kit, 110VAC — $19.95

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