Make:

technology on your time

3D Photos: View-Master's Untold Story

page 58 »

TOYS AND GAMES

- Bluetooth Arcade Controller
- RFID Talking Teddy Bear
- Giant Bubble Blower
- Pop Pop Steamboat
- Spy Video Copter

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MAKING SPOOKY SOUNDS WITH LIGHT

Build Your Own Retro Analog Synthesizer!

BY GARETH BRANWYN AND STEVE HOBLEY

Anyone who's shivered in the dark at a scary movie or laughed at the unintentional cheese-ball of bad sci-fi (paging Ed Wood) knows the eerie wail of the theremin. A Russian named Léon Theremin invented this strange instrument, which you play without touching, in the 1920s. The classic theremin uses two antennas as controllers. Radio waves, which change shape as you move your hands near the antennas, control the instrument's sounds and volume. For our project, we're building a simple theremin using interrupted photons (light) instead of radio waves. When we're done, we'll have a decent sounding theremin whose output can be experimented with by changing the type of light sensor used and the capacitance of the circuit.

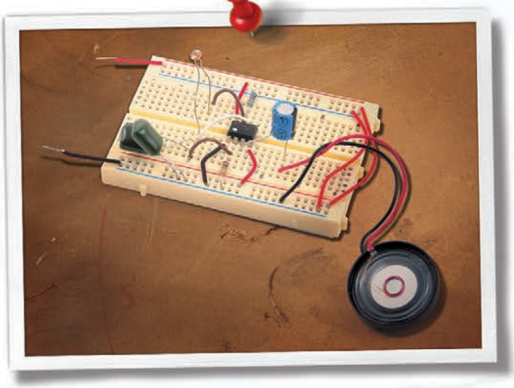
Where the theremin has a devoted fan base of builder and player hobbyist, the chip we'll use to create our oscillator has an equally fascinating history and following. The 555 integrated chip (IC) timer was designed by electronics engineer Hans R. Camenzind in 1970. An extraordinarily useful chip, it has remained popular and found thousands of applications. The 555 can operate in three main modes: monostable (as a one-shot pulse generator/ timer), bistable (a flip-flop switch) and astable (an oscillator). We'll be using it in astable mode.

Let's Get Started

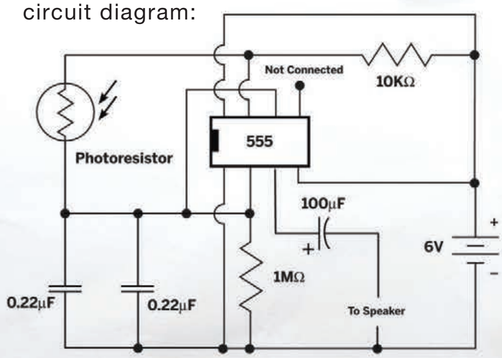
You will need all of the components found on the parts list to your right.

This project is built on a breadboard, a handy prototyping tool that allows you to plug and unplug components. Once you get the circuit working, you can solder it onto perfboard (RS #276-1396) to make it permanent, if you like.

Here is the circuit laid out on the breadboard.



See the completed project and larger breadboard images at makeprojects.com/Project/Light-Theremin/989 for more details. Refer to this circuit diagram:



ADVERTORIAL

Theremin demonstrates his instrument's spooktastic sounds.

Note: The electrolytic capacitor, 555 chip, and speaker are all polarity/orientation sensitive. Make sure you install them as seen on the breadboard and in the circuit diagram.

That's all there is to it! When your circuit is set up, apply six volts of power (e.g., via four 1.5V "AA" batteries) and you should hear a cool whining tone that changes as you move your hand over the light sensor. Experiment with different photoresistor (or other light sensors) and resistor values until you get the sound you like.

Good luck and spooky music-making to you.

PARTS:

1-LM555 Precision Timer, RS#276-1723

1-100µF Electrolytic Capacitor, RS#272-1028

1-(5-pack) CdS Photoresistors, RS#276-1657
(You'll need one for this project)

2-0.22µF Capacitors, RS#272-1070
(or 1-0.47µF cap)

1-(Pack) 1/4-Watt Carbon-Film Resistors, RS#271-312
(You'll need one 10KΩ and one 1MΩ for this project)

1-8Ω Mini Speaker, RS#273-092

1-4-cell "AA" battery holder, RS#270-409
(Use this or some other means of delivering 6V to your finished circuit)

4-"AA" Enercell batteries, RS#23-849

1-Modular IC Breadboard Socket, RS#276-003

Make: Volume 28

TOYS AND GAMES

48: Coffee Table Arcade Console
Build a wireless, arcade-quality joystick-and-button console.
By John Baichtal and Adam Wolf

53: Eye in the Sky
Hack a hobby copter with video and see what the birds see.
By I-Wei Huang

56: Chinese Checkers for Two
The classic game, streamlined. By Charles Platt

58: Envisioning the View-Master
A fond, 3-dimensional look at the famous stereoscopic toy.
By Bob Knetzger

64: Toys from Trash
Arvind Gupta's playful educational mission. By Rohit Srivastwa

66: Clothesline Races
Which robot can travel the fastest along 100 feet of cable?
By John Baichtal

70: Pop Pop Steamboat
Toy steamer runs on a flame and the water it's in.
By William Abernathy

76: Permission to Play
A roundup of super fun toys and games, DIY and off-the-shelf.

Columns

11: Welcome: Toy Stories
Toys can inspire you to see the world differently.
By Dale Dougherty

12: Reader Input
Skateboard makers, tougher steel, and Spazzi blowback.

15: Maker's Calendar
Events from around the world. By William Gurstelle

16: In the Maker Shed
Spread the spirit of making. By Dan Woods

26: Tales from the Web
Let the games begin. By Gareth Branwyn

27: Making Trouble
A curriculum of toys. By Saul Griffith

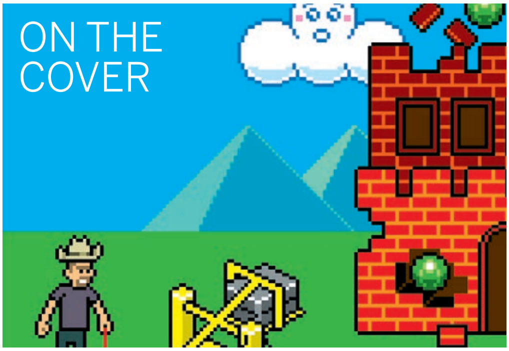
28: Soapbox
Is it time to retool public libraries as TechShops?
By Phillip Torrone

30: Country Scientist
Record your world from a Picture Post. By Forrest M. Mims III

33: Make Free
What my wife taught me about toys.
By Cory Doctorow

You can make it!
Family fun project

ON THE COVER



FLIPPING BITS: William Gurstelle, trebuchet aficionado and author of *Backyard Ballistics,* wrote our Gravity Catapult project on page 84. Art by eBoy. Art direction by Jason Babler.

FULL STEAM AHEAD: Toy boat makes its way across the high seas (or your bathtub) a pop at a time.

COINLESS COIN-OP: Our wireless joystick-and-button cabinet recreates that 80s arcade feel.

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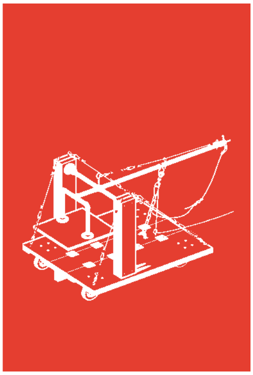
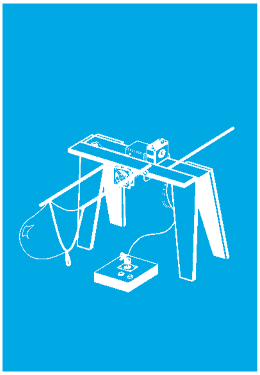
Make: Projects

Gravity Catapult

Get medieval with this portable, stowable, gravity-powered trebuchet.
By William Gurstelle

84





Gigantic Bubble Generator

Blow enormous soap bubbles with this Arduino-controlled Bubblebot.
By Zvika Markfeld

94

RFID Teddy Bear

Mod a plush toy and make it talk to other objects — and to you.
By David Harris

106

Beatjazz Controller

This sci-fi wind instrument makes music that moves.

By Onyx Ashanti

BUILD NOTES

Make: Volume 28

Maker

18: Made on Earth
Snapshots from the world of backyard technology.

34: Balsa Dreams
Paul K. Guillow's model airplanes have been buzzing over parks since 1926. By Andrew Leonard

40: Science in Your Cereal Bowl
These famous cereal premiums were tiny — but packed with mighty scientific principles. By Bob Knetzger

44: Strumming Up a Business
How a kids' bike inspired the creation of a cool new guitar kit. By Rafael Atijas

82: 1+2+3: Mini Foosball Game
Put together your own foosball game with just a few straws, paper clips, and a microwave popcorn box. By Cy Tymony

115: 1+2+3: Burnt Cookie Deflector
Avoid burnt cookies with a radiation-deflector shield made from aluminum foil. By Thomas R. Fox

150: Howtoons: Bubble Trouble
By Saul Griffith and Nick Dragotta

152: Toys, Tricks, and Teasers
Dropping a magnet through an aluminum tube takes longer than you think. Why? By Donald Simanek

155: Toy Inventor's Notebook
Take 3D photos with your camera. By Bob Knetzger

156: Danger! Make a Slingshot
Your own hand-powered projectile weapon. By Gever Tulley with Julie Spiegler

158: Toolbox
Arduino meets iPhone at last! The best tools, gadgets, and resources for makers.

166: Electronics: Fun and Fundamentals
Make an electronic rock-paper-scissors game. By Charles Platt

169: 1+2+3: Sneaky UV Ink
Protect your passwords from the naked eye. By Cy Tymony

170: Remaking History: Archimedes and the Water Screw
Re-create the invention that quenched the Egyptian desert. By William Gurstelle

176: Homebrew: My Home-Built Chairlift
By Jeff Johnson

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

34

FLIGHT SCHOOL: Andrew Leonard and his 13-year-old son, Eli, bond when building model planes.

DIY

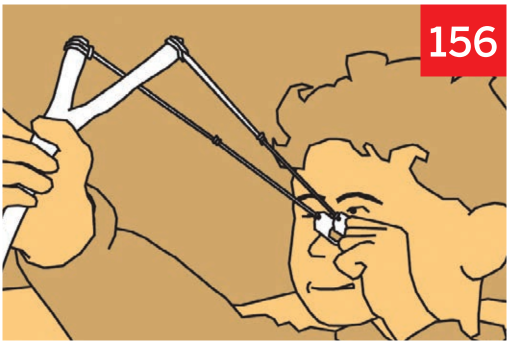
124: Science
PVC Van de Graaff generator.

128: Workshop
Homemade watch wrench, copper tool tidy.

132: Outdoors
Plant light stand, solar wax heater.

141: Home
Toddler swing, water leak detector.

146: Circuits
Solar pendulum.



156

SLINGSHOT: Who says primitive tools can't be fun? Ready, aim, fire!

“We don’t stop playing because we grow old, we grow old because we stop playing.”
—*George Bernard Shaw*

Make: technology on your time

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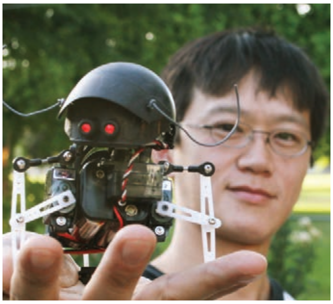
CONTRIBUTORS

eBoy (cover illustration) is **Kai Vermehr**, **Steffen Sauerteig**, and **Svend Smital**, "three guys working with image modules which we combine to form complex artwork." Svend lives in Berlin, and Steffen and Kai live in Vancouver, B.C., with their wives and kids, but they manage awesome collaborations across time and space. They are currently working on posters of Rio de Janeiro and FooBar 2, "an up-to-date version to our internet-themed poster." In their free time, they enjoy "video gaming, swimming, carving wood, playing drums, listening to music, podcasts, and reading." And they sleep a lot.

Jen Siska (*Balsa Dreams* photography) grew up in Illinois, studied photography at the Art Institute of Atlanta, and has made her home in San Francisco for 13 years. She just started a wedding photography business (lovebirdphoto.net) and hopes to one day buy land in Joshua Tree, Calif., to build her dream house. She enjoys trying new restaurants in the city, horseback riding on the beach, and working on creative projects with friends. Fortunate to have a career that allows her to travel, she recently spent time shooting a story in Marfa, Texas, and is looking forward to her next shoot in Asheville, N.C.

David Harris (*Charlie's Bear*) started designing electronic circuits when he was 7, and that love has waxed and waned over the intervening 30 years. He's passionate about science but thinks it's too stuck in old ways to be as effective as it could. As a result, he runs a science communication business and is most interested in hacking the processes of science through effective design and innovative communication. Outside of work, he tinkers with electronics, works on his balcony garden, rock climbs, and spends as much time as he can in California's wine country.



I-Wei Huang (*Video Copter*) is drawn to "any sort of visual problem solving." He loves "drawing, designing, hacking, tinkering, brainstorming, and even just playing games." He's well known for making steam-powered robots under the pseudonym CrabFu, is the youngest person inducted into the Craftsmanship Museum, and has won five gold medals at RoboGames. He's the lead character artist at Toys for Bob, and has spent most of his life making his character designs come to life, "whether it's on paper, through animation, or with physical objects and machines." See more of his work at crabfu.com.

Craig Couden (editorial intern) doesn't have a technical background, but thinks "the great thing about MAKE is that it's accessible to everyone on some level." He's currently working on adapting the Tron Bag project from CRAFT to make "a sweet *Tron: Legacy*-inspired jacket." He still loves Lego, is "totally into board games," loves to read sci-fi ("the weirder the better"), and is intrigued by 3D printers ("I'm fairly certain that if I didn't work here I would still think they were science fiction"). He lives "the glamorous life of a MAKE intern" in Petaluma, Calif., with his parents, sister, and dog, Jake.

Zvika Markfeld (*Gigantic Bubble Blower*) is a "self-educated software architect who recently decided to leave the IT business for industrial design school, trying to catch up with the childhood dream of becoming an inventor." Current projects include a moon gravitation harness, using meteorological balloons "to simulate the experience of walking on the moon while staying on beloved mother planet Earth," and a sign-language translator glove, "combining an Arduino, Android phone, a few flex sensors tied to a glove, and some beefy algorithms." He lives in Tel Aviv with his spouse, Noam, occasional stray cats, and gigantic soap bubbles.

WELCOME

By Dale Dougherty

Toy Stories

"I LOVED SHRINKY DINKS AS A KID!" exclaimed Michelle Khine, a biomedical engineering professor I met at a weekend summer camp for scientists called SciFoo, held at Google and organized by *Nature* magazine and O'Reilly Media. Khine explained how Shrinky Dinks toys inspired her to come up with a new nanoscale process that led to her startup, Shrink Technologies.

By creating a design at larger scale and then shrinking it down, Khine was able to find a simple and inexpensive method of making microfluidic channels for what she calls a "lab on a chip." Her early prototypes were printed on a laser printer and then baked in a toaster oven. One use of this process was to create saliva-based assays for infectious diseases.

We thought about stories like Khine's as we put together this Toys and Games issue of MAKE. Toys have inspired a lot of makers and spurred some surprising inventions.

Jose Gomez-Marquez had another toy story at SciFoo. The director of the Innovations in International Health Lab at MIT, he's designing DIY kits for deploying medical devices in developing countries. Much of their medical equipment comes secondhand from developed nations, and practitioners often must customize or hack the devices to repair them — sometimes using toy parts.

"When you need a part, you don't have access to McMaster-Carr or any parts supplier," Gomez-Marquez said. "There's an amazing supply chain for toys, so you can find them everywhere. From a toy helicopter, I can find a rack and pinion system."

Johnny Lee was also at SciFoo. Lee, who wrote a popular article in MAKE Volume 01 on how to make a $14 Steadicam, now works at Google in R&D. Years ago, he created a novel whiteboard application for the Wii controller. Then he worked at Microsoft on the Kinect platform. He was one of the first to look at game devices as a cheap source of powerful sensors for use in other applications. Once the Kinect was hacked open, developers had a source of sophisticated computer vision technology for lots of unexpected applications. Willow Garage, a maker of telepresence robots, replaced a $20,000 computer vision system with an off-the-shelf Kinect.

I recently enjoyed a 30-course dinner prepared by The Cooking Lab's Nathan Myhrvold and Maxime Bilet, authors of the epic new cookbook, *Modernist Cuisine*. It's an impressively large effort to understand and explain the science of cooking and how to use such knowledge to develop new techniques and recipes. The Cooking Lab team works in a kitchen inside a machine shop inside an R&D lab. For this dinner, there were more cooks preparing the meal than people eating it.

One of the last courses was Myhrvold's take on gummi worms, made from a gel infused with olive oil, vanilla, and thyme. The gel was poured into a mold used for making commercial fishing lures. Eating these candies was a delight, turning us into kids dangling a wiggly worm above our mouths. It reminded me of food-making toys like Incredible Edibles, a 1960s-era Mattel toy whose secret ingredient was called Gobble De-Goop. I remember dozens of molds for making insects with frightening appendages.

This issue of MAKE is full of talking bears, bubble blowers, toy boats, racers, robots, and View-Master 3D slides. They're all fun projects to make, and they just might inspire you to see the world differently — as something you can shape, mold, shrink, and hack.

Dale Dougherty is founder and publisher of MAKE.

READER INPUT

From Makers Like You

Skateboard Makers, Tougher Steel, and Spazzi Blowback

Regarding the DIY skateboard project in MAKE Volume 26 (“World’s Simplest Longboard”), I’ve found Titebond III glue to be more effective for longboards, rather than Gorilla Wood Glue.

Also, the Baltic birch plywood is crucial to this project. The birch plywood “handy panel” found at home improvement stores is just that, handy — but it’s not as solid. You can find Baltic birch plywood at Woodcraft stores.

—Ben Klebe, Lexington, Mass.

Very cool project! I made a longboard for my son and I’m making a second one. Really a sweet ride! Here are some pics.

At 8" by 48" it’s a smooth, easy ride. I ordered the wheels and trucks from Amazon and didn’t notice I bought the Bigfoot brand, which are about twice the size of regular wheels. Because of the wheel size, the board looks like a regular skateboard enlarged on the Xerox about 150%! (I threw my daughter in there for scale.) Once school’s done there will be surfing in the streets!

—Mike Adair, Overland Park, Kan.

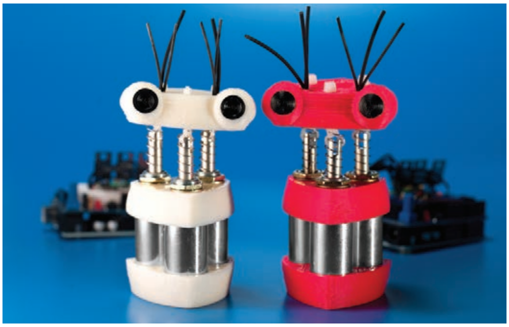
Very cool design! I just finished my first longboard for my niece to take back to school. She is a huge Dr. Who fan.

—Tod Tyler, Camp Hill, Pa.

I love the design you painted on the underside of the skateboard. Very fun and cool. What was your inspiration?

—Judy Murdoch, Denver, Colo.

EDITOR-IN-CHIEF MARK FRAUENFELDER RESPONDS: I really like the work of Jim Flora. He was a jazz record art director in the 1940s and 1950s. He was really good at making visually exciting designs using just a few colors. You can see some of his work at jimflora.com/gallery/recordcovers.html.



To build your own longboard and share your experience, visit makeprojects.com/project/s/709. And to see more DIY longboards, check out the MAKE Flickr pool at makezine.com/go/longies.

In the list of materials for making your own "Spoon Carving Knife" (Volume 27, page 123), the blade is made of "steel." If one were to go get a random piece of "steel" from somewhere, it would not respond as desired to the heat treating process described in the article — after heating it red-hot and quenching it in oil, then baking it in the oven, it would most likely be softer than before.

Normal, garden-variety steel is relatively soft and ductile, a great property for the general structural uses it's meant for. It's very forgiving: you can overload it and it will bend long before it breaks. But it makes a pretty crappy knife blade.

To make tools like knives, you need to use *tool steels* — and there are thousands of different ones for every conceivable purpose. What would work well for your knife would be alloys O-1 (letter O, not zero) or W-1. D-2 would make a blade that would hold an edge longer but be a little harder to sharpen. These steels are fairly inexpensive and are readily available from places like McMaster-Carr or onlinemetals.com.

Another excellent alternative, as you mentioned, is an old dull file — they can be forged when heated red-hot from a charcoal barbecue. If cooled slowly from forging temperature, they are quite soft and easy to shape. When hardened as described in the article, they get a good balance of hardness and toughness.

One of my occupations is designing equipment used to build jet wings. I use a lot of tool steels in my equipment. We live and die by good heat treating!

—Paul Shemeta, Seattle, Wash.

AUTHOR DOUG STOWE REPLIES: You're right, mentioning the specific kind of steel used would have been helpful. I used tool steel scraps from a friend who makes planes (woodworking planes, not airplanes). As I mentioned, old files can be a source of quality tool steel; another source is old handsaws that can be acquired in flea markets. Band saw and hacksaw blades can be used to make a thinner, more flexible knife blade.

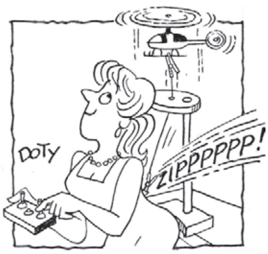
Did you geniuses bother checking a dictionary before naming your project Spazzi (Volume 27, "Spazzi: A Solenoid-Powered Dancebot")? Spaz is a synonym for retard in much of the English-speaking world.

—Anonymous

AUTHOR MAREK MICHALOWSKI REPLIES: Well, Spazzi uses the Arduino microcontroller, from Italy. The Italian word *spazzi* is a reference to sweeping, which is suggestive of the movement of the antennae/eyebrows atop Spazzi's head. Interestingly, several people have singled out those little add-ons as key to the dude's personality!

EDITORS REPLY: No offense was intended — in the U.S., *spaz* is generally a non-offensive term akin to *klutz*.

MAKE AMENDS



In Volume 27, page 160, we incorrectly labeled Roy Doty's Eureka comic strip "Phffft!" The correct title is "Zippp!" We apologize to Roy, and to fans of onomatopoeia everywhere.

In Volume 27's "Yellow Drum Machine" robot project, the AXE20 connection diagram (page 47, Figure T) is mislabeled. The Output connections should be indexed 07–00 reading downward (not upward). The corrected diagram is online at makeprojects.com/v/27.

Robert Bridges: Providing Shelter with the Help of a ShopBot

Robert Bridges is a carpenter, woodworker, designer, and pioneer in the use of CNC tools in the construction industry. A strong desire to help those in distress inspired the Shelter 2.0 project, to both supply housing to those in need and to encourage innovation in the production of emergency and transitional housing. "*Hearing about tent cities popping up around the country due to the economy, and then the devastation in Haiti, inspired me to do something. That's how the Shelter 2.0 project got started.*"

WHERE Eastern Shore of Virginia

BUSINESS Shore Tech Mfg *shoretechmfg.com*

SHOPBOT PRSalpha 96 X 60

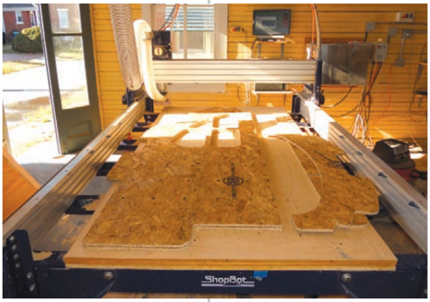
INSPIRATIONS "*These guys got me thinking about building in a whole new way – how to move from traditional processes to digital fabrication*":

ShopBot's **Bill Young**, boat carpenter and digital fabrication designer, who introduced Robert to CNC technology.

Prof. **Lawrence Sass, Dennis Michaud and Daniel Smithwick** from MIT. They built the full-scale "Digitally Fabricated House for New Orleans," exhibited at MoMA.

WHAT'S NEXT Raising funds to bring shelters to Haiti (visit shelter20.com to contribute). "*My ultimate goal is to get this technology in the hands of people who can learn it and build for themselves.*"

To download the design files to make your own Bridges-designed Shelter, snap this code with your smartphone, or visit www.shelter20.com.



Robert designed and cut his shelter using ShopBot Tools. It has a floor, room for insulation, and can house four people. The shelters are also being used as MakerSheds at Maker Faires around the country.

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.

Mars Science Laboratory

November 25, Cape Canaveral, Fla.

NASA's Mars Science Laboratory mission is preparing to softly land a large, mobile laboratory — the 10-foot-long, 900-kilogram rover *Curiosity* — on the Red Planet. Mission planners hope for a two-year window of exploration in which the machine travels portions of the Martian surface. The latest and greatest in interplanetary exploration begins with a November Atlas V rocket launch at Cape Canaveral.

NOVEMBER

» Bay Area Science Festival

Oct. 29–Nov. 6, San Francisco Bay Area

Featuring more than 100 fun, interactive science and technology events hosted at venues from Santa Rosa to San Jose, this festival features provocative lectures, hands-on activities, exhibitions, tours of science and technology facilities, guided hikes, and stargazing. bayareascience.org

» Fabtech

Nov. 14–17, Chicago

Metalworkers are some of the most skilled artisans of the fabrication world. By joining, bending, and cutting metals, they create everything from artworks to railroad engines to skyscrapers. Fabtech is the largest exhibition of welding and metal-forming gear anywhere: equipment displays, educational and training programs, and special events. fabtechexpo.com

DECEMBER

» The Royal Institution Christmas Lectures

Dec. 12–17, London

This extraordinary series began in 1825 with Michael Faraday's presentation of lectures for young people. Luminaries since then include David Attenborough, Carl Sagan, and Richard Dawkins. This year's theme: Meet Your Brain. rigb.org

» Asia Game Show

Dec. 23–26, Hong Kong

Nearly 400,000 visitors from around the world head to Hong Kong to discover the latest in online gaming technology and digital entertainment. This Christmastime expo also features educational seminars and lots of hands-on gaming. asiagameshow.com

JANUARY

» Light in Winter Festival

Jan. 20–23, Ithaca, N.Y.

Upper New York State shakes off the doldrums of a dark winter with a wide-ranging festival for anyone with either a passing or passionate interest in art or science. Expect science comedians, lecturers, musical performances, and much more. lightinwinter.com

» Global Game Jam

Jan. 27–29, Worldwide

GGJ is about collaboration using open source hardware and software. Participants are given a theme, and then set loose to create a new and hopefully fun-to-play game — in 48 hours or less. Last year, GGJ teams in 44 countries created more than 1,500 games. globalgamejam.org

*** IMPORTANT: Times, dates, locations, and events are subject to change. Verify all information before making plans to attend.**

MORE MAKER EVENTS: *Visit* ***makezine.com/events*** *to find classes, fairs, exhibitions, and more. Log in to add your events, or email them to* ***events@makezine.com****. Attended a great event? Talk about it at* ***forums.makezine.com****.*

IN THE MAKER SHED

By Dan Woods

Happy Holidays from the Maker Shed!

SINCE LAUNCHING MAKE SEVEN YEARS ago, our mission has been to inspire, inform, and connect the global community of makers — and aspiring makers. A central goal of our work is to help people get started with making.

And so it was at the end of our first Maker Faire that we thought, "How cool would it be if people could take home a slice of Maker Faire in the form of a kit they could do afterward to keep the magic alive?" Meanwhile makers kept asking us, "What ever happened to the chemistry sets and Heathkits I remember?"

We began to see an opportunity taking form. From this simple precept, we grew the Maker Shed store as a key element of the MAKE experience.

Since then, the Maker Shed has taught more than 10,000 people to solder; helped over 100,000 customers get started making or learn a new technology with our DIY kits, tools, and supplies; and supported dozens of independent makers launching their own small businesses, by writing about their products and carrying their early-stage kits in the Maker Shed store.

Those are achievements we're proud of, but we've only scratched the surface. We know there are so many more makers out there just waiting to get their hands dirty.

We respect that not everyone celebrates the holidays, or chooses to do so with gifts. However, if you do, we hope you'll give friends and loved ones the gift of making this season.

If you're a subscriber, you'll find our first-ever Maker Shed catalog mailed with this volume of MAKE. (If you're reading someone else's copy or bought yours on the newsstand, you can find our catalog at makershed.com/catalog).

Whether it's for a subscription to MAKE, one of our hands-on Make: Projects books,

or DIY kits or tools, please consider shopping in MAKE's own store this season, and spread the spirit of making.

And for even more gift ideas, look for our new special issue, the MAKE Ultimate Kit Guide, on newsstands Nov. 22, and at makershed.com (item #KITSIP). You'll discover 200 top DIY kits: rockets and robots; beverage-making and bicycles; chemistry and crafts; aircraft, automotive, and adventure; music, marine, and more. Revisit classic kits, and meet state-of-the-art kit makers like Wayne and Layne, Adafruit, Spikenzie Labs, *Wired*'s Chris Anderson and his DIY Drones, and many more. It's a gift guide that makes a great gift in itself.

Dan Woods is MAKE's associate publisher and general manager of e-commerce.

Maria Beate Wegner

Machine Soul

German designer and furniture maker **Frank Buchwald** says he's fascinated by the "uncompromising functionality of machines," and he prefers to experience it raw, unobscured by exteriors of mawkish or overly pleasing design.

Machine artifacts from the industrial age best epitomize the raw quality that captivates Buchwald. His Machine Lights series of sculptural lamps consists of 12 different models, handmade from up to 200 individual parts over a period of at least four weeks. Materials include burnished steel, brushed brass, textile cables, and blown glass.

Before he began designing furniture and lights, Buchwald worked as an illustrator and painter. To this day he begins his projects with sketches so he can remain free to follow ideas, impressions, and associations as they arise. This nascent, spontaneous phase is crucial, he says, in finding out "the essence, the character of a new object."

While they have the appearance of romantically arcane technologies, the Machine Lights also have a creature-like feel to them. Buchwald cites the converging influences of art, architecture, and the natural world as responsible for his lamps' "techno-biological character."

Buchwald sees a hidden principle at work in the world of machines. "An independent reality, removed from human access, exists behind the manifest appearance of mechanical objects," he explains. It's this principle, the secret nature of mechanical reality, that he attempts to examine and expose with his Machine Lights series.

—Thomas Wilson

» **Sculptural Light:** frankbuchwald.de

Gnarly Biogenesis

When the snow melts in the mountains outside the tiny village of Stropones, Greece, artist **Achilles Kapsalis** can be found collecting animal bones for his *Psyteks* sculpture series. Kapsalis breathes wicked new life into the bones, resurrecting them as fierce, bionic creatures born of his imagination.

Kapsalis is a lifelong maker, with a childhood full of creating the new and repairing the old, alongside his passion for collecting action figures of characters from favorite artists like H.R. Giger, Stan Winston, and Clive Barker. He'd dabbled in conceiving his own characters, but until April 2008, had directed much of his creativity toward making furniture.

The word *Psyteks* is a twisted portmanteau of *psychology* and *technology*, his own "healthy version of artistic psychosis" combined with a unique view of mechanics. *Psyteks* each begin with metal, his material of choice, as a foundation to add animal bones to, without the use of glue or welds, which he adamantly opposes. For parts that don't dry-fit well, he employs the occasional screw.

Kapsalis sources native bones from Stropones and others from the internet. For the metal, he prefers found objects with readily identifiable shapes. In *Gnathotek*, two found dog skulls rage as one, spewing forth multiple razor-tipped bike chains, while the assemblage that is *Otomorfius*, the wheeled creature of doom, was once an antelope skull and a pile of industrial gears, bearings, R/C car parts, and a machine-cutting tool.

Though Kapsalis' creations aren't as familiar as the animals they came from, the sheen of the bones and the luster of the metal seem harmoniously mated and freakishly natural, like a scene from a futuristic fairy tale where supercreatures roam the Earth.

—Goli Mohammadi

» *Psyteks* **World:** psyteks.com

Achilles Kapsalis

Dave Cloud

Dolphin Car

Remember the Geo Metro? Introduced in 1989, the vehicle's been awarded more ridicule than anything else. And while the Geo brand is now defunct, EV enthusiast **Dave Cloud** of Woodinville, Wash., could earn the car some newfound recognition. He has created the Dolphin car, an electrified version of a 1997 Geo Metro with an overall fuel economy of 214mpge (miles per gallon equivalent).

"My goal was to build a vehicle that can go 200 miles on a single charge with a speed of 60 to 65 miles an hour for 85% of the miles, for under $3,000. I accomplished this goal," acknowledges Cloud, who has completed more than 45 EV conversions.

The full conversion took about a year to complete. The Metro's original fuel-sipping, front-wheel drivetrain was replaced by two 8-inch series-wound DC electric motors, one at each rear wheel. Each motor, individually controlled using a 72-volt, 400-amp controller, has its very own battery pack made up of 30 lead-acid, 12-volt cells. Cloud streamlined the body beyond recognition, and with the low drag of its slippery dolphin-inspired shell, the car tops out around 72mph. But at 3,200lbs, it's sluggish right out of the gate, hitting 60mph in just under 20 seconds.

The Dolphin's fuel economy is impressive, but the original Metro actually held its own. In fact, the car made a slight comeback in 2008 due to rising fuel costs. As a result, it was tested in the July 2009 issue of *Car and Driver* alongside the newly redesigned Honda Insight and the Toyota Prius. It tied with the Prius for overall fuel economy at 42mpg!

With gas prices continuing to push toward a national average of $5 a gallon, maybe the Geo Metro will make a comeback à la the Fiat 500. Unlike dolphins, I wouldn't hold my breath.

—Jerry James Stone

» **Dolphin Stats:** evalbum.com/3242

Big Wheels Turnin'

Fred Abels has a fascination with wheels. "The idea of two giant wheels that can overcome any obstacle has always appealed to me," says the 50-year-old Amsterdam native. So, together with friend **Maik ter Veer**, Abels created the Dicyclet — not only a monster of a vehicle, but also a dream come true.

Dicycles — bicycles with wheels that ride parallel rather than in a line — are nothing new: E.C.F. Otto patented his own "Otto Dicycle" in 1881, but, says Abels, "His positioning of the driver above the axle resulted in a serious balance problem." In Abels' version, which is equipped with wheels 8½ feet in diameter spaced 4 feet apart, the driver sits below the axle, keeping the center of gravity low and allowing equilibrium.

While the device itself is straightforward, steering takes forethought. To make a turn, one wheel must move slower than the other, so Abels uses a differential to connect them. When a rider hits the left brake, the Dicyclet turns left by transferring energy to the right wheel, and vice versa. Riders can also do a complete flip by quickly accelerating then hitting both brakes hard.

Among Abels' other creations is the Cotyl, a giant onion-shaped capsule topped with a 79-foot-tall wooden pole, all suspended in a 2-axis gimbal set that allows free movement. Up to eight people can climb inside and experience the motions and sound of the wind.

Though the Cotyl capsule has since been disassembled, Abels' often-imitated Dicyclet, which has appeared at festivals in the Netherlands, Ireland, and Stonehenge, England, remains rarin' to go.

—Laura Kiniry

» **Rethinking Wheels:** fabels.org

Maik ter Veer

Martijn Roos

Bus(t) a Move

Superbus is a 49-foot-long, astronaut-designed carrier that hauls more than 20 passengers and tops out around 155mph. If Batman carpooled to work, this would be his ride.

It's powered by a 300kW electric motor, which roughly translates to 400 horsepower, backed by a lithium polymer battery pack. It even makes use of regenerative braking.

With its driving range of 125 miles, the Superbus won't get you that far out of Gotham (sorry, Batman), but its couch-like comfort, internet access, and TVs for every passenger give it all the perks of flying first class without that awkward TSA pat-down.

The limo-esque vehicle was constructed using state-of-the-art, super-light carbon fiber and cost $19 million to build. A design team from the Netherlands' Delft University of Technology unveiled the Superbus earlier this year in Dubai at a public transportation exhibition. The team includes astronaut **Wubbo Ockels**, the first Dutch citizen to make it into space; **Antonia Terzi**, who worked on the BMW WilliamsF1 racing team; and aerospace engineer **Joris Melkert**.

"The Superbus can drive everywhere a normal bus can drive," explains Ockels. In fact, its four rear wheels turn independently of each other, giving the vehicle a turning radius of about 41 feet.

That's impressive agility considering its unwieldy stature, but nevertheless its high speeds require extra safety measures. So passengers have their own individual airbags, and the vehicle uses an onboard radar system to detect obstacles.

The prototype took seven years to build, and if it passes government inspection, it will soon be cruising around the United Arab Emirates. *—Jerry James Stone*

» **Dubai or Bust:** superbusproject.com

Beer Wheel Drive

Caz Sienkiewicz's City Cycle has bike chains, bike saddles, crank sets, and no engine. And yet, it's really more of a car project than a bike project. Designed to hold fourteen 250lb people and their beverage of choice, it's built to support more weight than a Dodge Ram 2500 pickup, and the motor vehicle similarities don't end there.

The front end was designed for a Ford Mustang II and the rear suspension system for a Ford Crown Victoria. Explains Sienkiewicz, "Even though it tops out at 5 miles an hour, the chassis is built for 100 miles an hour. It's a hot-rodder chassis."

Building it in his garage in Minneapolis over one winter meant working in tight conditions, especially with TIG and MIG welders, chop saws, and CAD workstations lining the walls.

Massachusetts-born Sienkiewicz is an experienced machinist and engineer. His firm Caztek makes machinery for the biomedical and computer industries. In his spare time, he's working on a valveless pulsejet.

So what's the City Cycle experience like? "One early design was geared differently, and we could get it up to nearly 20 miles an hour," recalls Sienkiewicz. But that was too fast, so he opted to change the gearing, to make it easier to pedal up hills. "Believe me, 5 miles an hour is plenty fast," he says. "And the automotive suspension provides a comfortable ride, with surprisingly good handling."

City Cycle riders can enjoy a brew or two during the journey, supplied from a midships beer tap hooked up to an insulated keg cooler in the back. Sienkiewicz hopes to sell his invention commercially. Before too long, a City Cycle might be pedaling around your neighborhood.

—*William Gurstelle*

» **Pedal-Powered Party:** citycycle.us

Ken Friberg

Colossal Camera

Darren Samuelson takes amazing, ultra-large-format photographs with a gigantic, handmade bellows camera.

After years of teaching himself how to shoot and process photographs using traditional film cameras, his desire to produce larger prints in his limited work space led him to create the massive piece of kit. With digital photography edging out film, prices for large-format sheet film continue to rise as inventories shrink. Learning that some folks use X-ray film as a cheap alternative to black and white photographic film, Samuelson discovered he could get X-ray film as large as 14"×36".

After contemplating how cool it would be to have a camera big enough to take a picture with film that large, Samuelson spent a year researching the materials and techniques he would need to construct such a mammoth camera. It took another six months and hundreds of hours spent using a Dremel tool, power drill, circular saw, and numerous hand tools to assemble his creation.

Its red oak and bamboo frame houses a handmade ground-glass back that accepts handcrafted film holders made from foam-core and illustration board. At 70lbs, with an extended bellows length of over 6 feet, the camera produces full-frame 14"×36" negatives that render extremely detailed contact prints.

Samuelson recently took the camera on a cross-country road trip, capturing national landmarks from the French Quarter in New Orleans to the geysers of Yellowstone National Park.

—Adam Flaherty

» **Say (Big) Cheese:** darrensamuelson.com

Mary Tran

TALES FROM THE WEB

By Gareth Branwyn, Makezine.com Editor-in-Chief

Let the Games Begin

WE'VE POSTED OODLES OF ARTICLES AND PROJECTS on makezine.com related to gaming, from tabletop wargames to video game console hacks to such outdoor geek pastimes as geocaching. Here are a few of our favorites. Find more in our online Gaming category (blog.makezine.com/archive/category/gaming).

How-To: Custom Dice via Toner Transfer

From Barcelona dice hacker Abraham Neddermann (aka Dicecreator) comes this cool and straightforward project for creating your own dice using inkjet paper and a laser printer. makezine.com/go/tonerdice

Gaming Racing Cockpit in an Ottoman

An Australian gamer built this full-featured racing game cockpit housed in an ottoman that stows away everything when not in use. An Automan? makezine.com/go/automan

How-To: Shrink-Film Gaming Minis

One of our favorite gaming projects is from MAKE contributor Sean Ragan: use polyolefin shrink film to create simple, handsome custom game components. Check out his full how-to: makeprojects.com/project/s/346

Gaming Minis From Twist Ties

Miniature gaming can be an expensive hobby, but enterprising maker "Ionustron" proves that it doesn't have to be — he fashions his gaming figures from twist ties! makezine.com/go/twistminis

Intricate 3D-Printed Gaming Dice

Shapeways and other 3D printing services (and home 3D printers like MakerBot) are revolutionizing tabletop gaming — suddenly players can design and print out their own custom figures, playing pieces, and dice. Here's a gorgeous set of Thorn Dice designed by Chuck Stover and available through Shapeways. makezine.com/go/3ddice

Homebrew Video Game Cartridges

MAKE contributor Joe Grand offers detailed plans (and downloadable PCB files) for creating your own Atari 2600, Atari 5200, Atari 8-bit, and ColecoVision game cartridges. makezine.com/go/diycartridge

Cansole: Arduino-Based Game Console in a Can

When author John Graham-Cumming (*The Geek Atlas*) isn't surveying global geek travel destinations, he's building things like this gaming console housed in a candy tin. makezine.com/go/cansole

Gareth Branwyn is editor-in-chief of makezine.com.

MAKING TROUBLE

By Saul Griffith, Omnivorous Inventor

A Curriculum of Toys

EVERY PUNDIT CRIES THAT EDUCATION IS broken. I'll say all we really need are good toys.

What are the fundamental things kids should know to help them understand, enjoy, and someday improve the complex physical world we live in? Could a curriculum of engaging toys be so powerful that the role of schools is reduced to mere socialization?

Here's my start at a list of core life skills I think can be taught by toys and play. I'd love to hear your ideas at makezine.com/28/trouble.

Drawing and Sculpting. Communicating ideas visually is critical for future makers. You needn't be Rembrandt; just learn proportion, perspective, and representation in 2D and 3D. *Chalk and a sidewalk, pencil and paper, an Etch A Sketch if you must. Play-Doh, clay, sandboxes, food, aluminum foil, paper and origami.*

Joining Things. Gluing, nailing, soldering, welding, lacing, riveting, taping, stitching, screwing, and tying knots. Give kids some rope, or a log, a hammer, and a bag of nails. *Any DIY kit or craft project, ropes, kites.*

Shaping Things. Cutting, sawing, chiseling, whittling, sanding, grinding, drilling. Give kids real tools, not cheap copies. *Woodworking tools, craft projects, penknife, scissors.*

Forces. Gravity, levers, projectile motion, friction, pulleys, gearing, torque. *Mobiles, trebuchets, magnets, juggling, throwing, ball or board sports, sailing, seesaws, slides, bicycles!*

Fluids, Hydraulics, and Pneumatics. *Water guns, water balloons, boats and rafts, blowgun darts, bathtubs, rivers, beaches, lakes, dams, skimming stones, bike pumps.*

Electronics. Voltage, resistance, current, and blinky lights. *Battery-powered toys (hack them), 9-volt batteries (lick them).*

Structures. Trusses, compression, tension, architecture, how things stand up. *Blocks, cardboard forts, sticks and stones, sandbox play, Erector sets, Lincoln Logs, treehouses.*

Energy. Conservation and momentum, transformation, generation, storage, and consumption. *Marbles, batteries, rubber-band airplanes, bicycles, dirt bikes, slot cars, train sets, swings, skateboards, kites.*

Math. Counting, arithmetic, geometry — just about any toy has a math lesson in it. *Beads, marbles, dice, Monopoly, cards, Tetris.*

Laughter. Life has to be fun, and toys should help us laugh. *Soap bubbles, Slinky, Pin the Tail on the Donkey, whoopee cushions.*

Natural Philosophy. The ways of the natural world, including geology and biology. *Magnifying glasses, magnets, telescopes, microscopes, buckets, nets, specimen boxes.*

Properties of Materials. Every toy is a materials science lesson, whether wood, plastic, or metal. *Oobleck, chemistry sets, cooking.*

Magic and Illusion. I love magic because it challenges you to search for the illusion — it's an opportunity to learn about reason and the scientific method. *Magic sets, brain teasers.*

Your Body. Dance, sport, climbing, swimming, hiking, gymnastics. *Go to the park!*

Storytelling. Children tell stories and release their imagination through whatever toy is in their hands. *Dolls, stuffed animals, wooden trains, Lego, Play-Doh, imagination.*

Logic. Building a Lego model or knitting a hand puppet is an exercise in basic instructional logic: do this, then that; if this happens, do that. *Construction toys, craft projects.*

Until our school system is reformed, I think the burden falls on parents, guardians, and friends to teach children the skills of life. Let's share the lessons and experiences embodied in the best toys. (But subtly. Kids can smell didactic like a giant adult skunk.)

Saul Griffith is chief troublemaker at otherlab.com.

SOAPBOX

By Phillip Torrone, Open Source Enthusiast

Is It Time to Retool Public Libraries as TechShops?

PUBLIC LIBRARIES — THE AVAILABILITY of free education for all — represent the collective commitment of a community to their future and to educating the next generation. The role of a public library should also adapt over time, and that time is finally here. It's time to plan how we're going to build the future and what place public libraries have, should have, or won't have.

At one time the library was "the living internet" — you went there to look up something hard to find, to do research. Now it's all at our fingertips through search engines, Wikipedia, and the web. So where does this leave libraries?

Recently I walked by the Borders on Broadway in New York City — it's going out of business. There are many reasons, but I think most people will agree giant collections of books in giant buildings don't make much sense (or cents!) any longer. Digital media are usually better online, available in our homes.

Let's explore what could be ahead for public libraries and how we could collectively transform them into "factories" — not factories that make things, but factories that help make people who want to learn and make things.

Will libraries go away? Will they become hackerspaces, TechShops, and Fab Labs, or have these new, almost-public spaces displaced a new role for libraries? Books themselves are tools of knowledge, so in that sense the library is already a repository for tools. Will we add "real tools" for the 21st century?

Where I live in NYC, there are two or three public libraries within a 15-minute walk. I really tried to use them, but the online interface wasn't great, the things I wanted to check out were usually taken, and it's hard to beat "instant" when I have a computer and web connection. Since the Kindle and Kindle apps came out, I haven't visited the library. Not everyone has an e-reader, but there are predictions that ultimately, e-readers will be free and e-books just 99 cents (that's less than a late book fine). I work with younger folks, and it's rare for them to have ever used a public library except at school.

Unless libraries are seen as the future, we might just lose them.

So where *have* I visited in the last few years that's a "public-like" space for learning? Hackerspaces, Fab Labs, and TechShops.

A *hackerspace* is usually a membership-based location featuring workshops, tools, and people who like to make things. Hundreds of hackerspaces have appeared, almost overnight; just about every U.S. state has one, and most large cities do too. Members pitch in to pay the rent and other shared costs. The cost to get one started is usually a year's rent in your local area for a good-sized location.

Fab Labs are associated with MIT, so they're more of a sponsored/academic effort. As of July 2010, there were 45 Fab Labs in 16 countries. I like that they all use similar equipment; standardization of laser cutters, CNCs, and computers is good if you're going to make something and you want others to be able to make it somewhere else. Getting a Fab Lab started can cost as little as $25,000, but realistically it's likely a few hundred thousand.

TechShop is a commercial venture that's membership-based, has pretty much all the equipment you need to make anything, and provides workshops and classes. There are currently four locations (Menlo Park, Calif., San Francisco, San Jose, and Raleigh, N.C.);

Timothy Archibald

New York and Detroit are to follow. TechShop hopes to have 100 locations in five years. They say it costs $1.5 to $2.5 million to get one started. That's not too much above the average yearly cost to keep a public library going. Can libraries be TechShops?

If the only public space where 3D printers, laser cutters, and electronics education happens is in fee- or membership-based spaces, that will leave out a segment of the population, who will never have access.

What if we were to convert just 1% or even 10% of the 9,000 U.S. public libraries to TechShops? One percent is about 90 libraries, close to TechShop's five-year target, and 10% would be 900 locations — not a bad goal.

But why does it matter? I think public libraries are one of those "use it or lose it" assets we have in a society. Given the current state of public budgets, I think unless they're seen as the future, we might just lose them.

» How can America be a world leader in design and engineering?
» How can we get kids access to design/build tools like laser cutters and 3D printers?
» How can we train each other for the jobs and skills needed in the 21st century?
» How can we spark the creativity and imagination of kids?

Many of these aims could be helped by the retooling of one of our greatest resources, the public library. It wouldn't be easy, but that's the point — it'd be a challenge worth doing.

We can wait and hope every state thinks about this, or that local hackerspaces can achieve something like it. But why wait? Libraries and librarians are underutilized for skill building. Libraries have the space, they have net connections, they're in great locations — why not evolve?

It's scary — laser cutters, CAD stations, CNC, 3D printers, equipment purchases, safety training — I'm sure there are lots of reasons it could never work out, but there are also many reasons it could. Besides, how often do you hear people talking about lining up outside the library because the new 3D printer has arrived and they want to use it?

What do you think the public library should be in the 21st century?

+ Share your ideas, and read the full version of this column, at makezine.com/go/libraries.

Phillip Torrone is an editor-at-large of MAKE and creative director at Adafruit Industries, an open source hardware and electronic kit company based in New York City.

COUNTRY SCIENTIST

By Forrest M. Mims III, Amateur Scientist

Record Your World from a Picture Post

SCENIC PHOTOS OF STORMS, CLOUDS, sunsets, mountains, and beaches are loaded with data about the natural world. Even pictures of backyards and parks can provide valuable environmental information.

For decades, NOAA and NASA satellites have collected images of the Earth from space. In recent years, ground-based webcams have captured views of scenic sites around the world. But organized sequences of high-resolution landscape and sky photos taken of the same scene over several years or more are not that common. This lack provides an important opportunity for amateur scientists to fill a huge data void. All that's necessary is a digital camera and a platform to place it on, so that it can be used to collect images at regular intervals.

The Picture Post Project

John Pickle, whose background includes geology and meteorology, is on the science faculty of Concord Academy in Concord, Mass. In 2005, Pickle began Picture Post, a carefully designed project to collect periodic sets of landscape images using a digital camera pointed in eight different angles from an octagonal platform mounted atop a post.

The Picture Post project made total sense to me. Since the fall of 2000, I've taken almost daily digital fisheye photographs from a post in a 1.5-acre field adjacent to my office. So far I've collected more than 2,700 images of the sky above and the horizon around the post.

While these photos were originally intended to record haze and clouds in the sky, it soon became obvious that the images were also recording changes in the trees and other vegetation around my site as well as a nearby field and farm. Seasonal changes were very obvious, especially the transformation of the landscape each spring and fall. Over the years, changes in the height of trees were noticeable. Those surface changes were accompanied by sky changes, especially haze from Asian dust and Mexican smoke during spring and African dust during summer and fall.

I didn't fully appreciate the environmental record these images provide until learning more about Picture Post, which is a part of Digital Earth Watch (DEW), a NASA-sponsored partnership of various organizations. According to the project's website, "Picture Post was created for DEW as a tool for nonscientists to monitor their environment and share their observations and discoveries."

How to Make and Install a Picture Post

My original "picture post" is just a 6' length of 4×4 lumber topped by a 17" length of 2×6 lumber that serves as an instrument and camera platform. Both are pressure-treated to prevent rot. Pickle's Picture Post design is better suited for recording both the surrounding landscape and the overhead sky.

While Pickle also uses a 4×4 post, he recommends a length of 7' to 8', 4' of which will be above ground. His camera platform is much more than a flat surface — it incorporates a raised octagon designed to permit a camera to capture a 360° sequence of images around the post. The camera is held with its back against each segment of the octagon, and an exposure is made. A ninth photo is then taken with the camera looking straight up.

While ordinary pressure-treated lumber can be used for the picture post, Pickle recommends a plastic composite post because of its virtually unlimited life. The top of my post is chest high (about 4', the same height recommended by Pickle), although young children might require a shorter post. A step stool

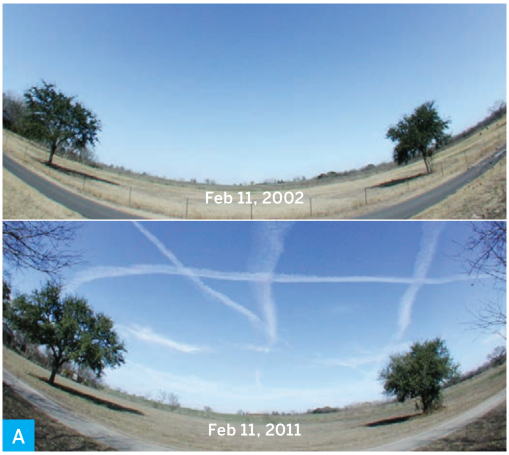


Fig. A: The north horizon at the Mims place photographed just after solar noon on the same February day in 2002 and 2011. Note the growth of the two live oak trees during the nine-year interval. The contrails in the 2011 image were a result of a damp sky.

Fig. B: This sequence of images from the Mims instrument and camera post shows the growth, bloom, and decline of a patch of native sunflowers. The central trail was kept open to record the north horizon.

Fig. C: Concord Academy student Will Jacobs takes a Picture Post photograph.

could be used, but this may not be practical for all outdoor situations.

You can make a camera platform for the post from 2 pieces of weather-resistant wood or plastic. Pickle recommends making the platform base by cutting a 9" circle or octagon from ¾" plywood. The camera octagon should be cut from ⅜" or ½" plywood with 2" sides and measuring 5" across facing sides. It should be centered over the 9" base and screwed or glued to the base with water-resistant adhesive. If the platform is made from wood, Pickle recommends waterproofing it with several coats of polyurethane. Full details are provided at picturepost.unh.edu.

To save time, you can buy a ready-made plastic camera platform (with a raised octagon and a recessed "N" to indicate north) for $25 from the Picture Post website.

When the camera platform is ready, it's time to install the post. Select a site that provides the best view of the surrounding landscape consistent with the vertical view. While you might be able to mount the camera platform on a fence post, deck railing, or other outdoor support, installing your own post provides more flexibility. A location that features views of both a distant horizon and nearby plants will provide a diverse record of the landscape. A vertical view that includes a bit of tree canopy will let you record seasonal changes while also tracking cloud cover.

Dig a hole at least 3' deep and wide enough for the 4×4 post. If you live in an area where the soil freezes, the hole should be deeper than the frost level. For example, in northern Minnesota, Pickle recommends that the bottom of the post be 5' below the surface (in which case, to maintain 4' of post above ground, you'd need an overall length of 9').

Place the post in the hole and roughly align it so that each side faces a cardinal direction (north, south, east, and west). Backfill the hole with soil while using a level to keep the post as vertical as possible. While the hole is being filled, tamp down the soil with your feet until it's firm and the post is stable.

The camera platform should be centered on top of the post and attached with four 3" to 3½" coarse-thread exterior drywall screws.

Forrest M. Mims III, John Pickle (C)

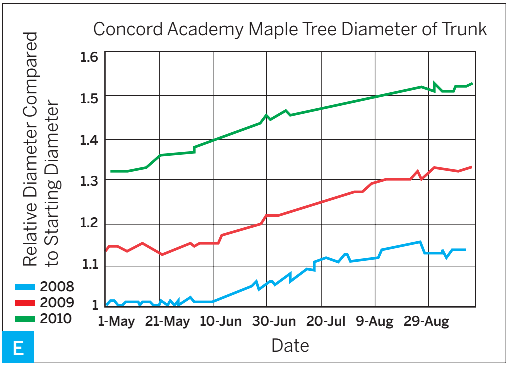


Fig. D: Seasonal changes looking northwest from the Concord Academy Picture Post.

Fig. E: Growth of a maple tree extracted from three years of Picture Post images by John Pickle.

Fig. F: Seasonal changes of the sky and a nearby tree looking straight up from the Concord Academy Picture Post.

Four matching pilot holes should be drilled into the top of the post, but only after it's oriented so that one side of the octagon faces due north. You can use a compass to find magnetic north, but you'll need to correct the reading to find true north. Pickle recommends using the declination chart at thecompassstore.com/decvar.html.

How to Use a Picture Post

The Picture Post program doesn't require daily photographs, and their website recommends that a set of photos be taken every week or two when possible. Based on my results, it seems best to take photos at solar noon (when the sun is at its highest point in the sky). If that's not feasible, it's best to take all photos at about the same time of day.

In my experience, more frequent photographs are important for capturing days with clear skies, haze, and cloud cover, and the rapid changes that occur to deciduous vegetation during spring and fall. Here are just a few examples of what you can do:

» Become a serious Picture Post participant by following the project protocols to document your site with 26 biweekly or 52 weekly sets of images.

» Expand your image collection by taking more frequent photos during spring and fall.

» Measure plant growth by taking daily images during spring.

» Take frequent sky photos, as the sky changes much more rapidly than the landscape.

» Make charts showing changes in your images over time. Use bar charts to indicate the fraction of the sky covered by clouds.

» String sequences of photos together to make elapsed-time videos or animated GIFs.

» Supplement your Picture Post archive by posting your photos on a website. Add information about data and observations from your site.

» Automated webcams provide a convenient way to record changing landscapes and sky. An archive of webcam images can be made into a movie that will show these changes over time.

How to Participate in the Picture Post Program

Anyone can participate in the Picture Post program. You can register your picture post on the Picture Post website (picturepost.unh.edu) and even submit your photographs. This will place your images into an archive for study by both amateur and professional scientists and anyone else.

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

John Pickle

MAKE FREE

By Cory Doctorow, Digital Rights Defender

What My Wife Taught Me About Toys Today

DIY DOLLS: Can 3D printing bring toy making back home? A prototype from MakieLab.

WHEN MAKE TOLD ME THIS ISSUE'S theme was toys and games, I realized I was going to have to take my work home with me. My wife, Alice Taylor (a former pro gamer who played *Quake* on the English national team), is running MakieLab (makielab.com), a startup whose goal is to deliver games and tools where kids will create virtual toys. Players will be able to press a button and have those toys printed on a nearby 3D printer and delivered to them. I picked Alice's brain for everything she's learned about toys. Here's the lowdown.

Toys don't have to be complex, and the market doesn't often value quality (McDonald's is the world's biggest toy maker, in the form of fall-apart Happy Meal toys). One stick makes a good toy, as my 3-year-old daughter can attest. Two sticks make an awesome toy. Throw in various bits of paper, cardboard, and plastic, and you've got play for days.

More than 95% of the world's commercial toys are made in China, often in the country's lowest-grade factories.

Non-Chinese toy making is a difficult business: between the high regulatory hurdles set by safety agencies and the razor-thin margins, mom-and-pop toymakers often go under or go offshore. Alice and I are sentimental bourgeois who love the idea of well-made wooden toys, and the brand we favored, Melissa and Doug, began sporting "Made in China" stickers not long after we discovered them. True to form, the last thing we got from them, a toy piano, had such poor build quality that it disintegrated in the first hour of play.

It's a funny example of the law of unintended consequences: the regulatory costs of ensuring that toys are safe have pretty much guaranteed that toys will also be junk. Alice is hoping 3D printing will be able to reverse that. She believes there'll be at least two markets for printed toys: first, the market for toys printed on high-end, expensive, patent-encumbered devices from Eos and Z Corp., which will require an intermediary like hers to produce, but which will also be well situated to go through the regulatory stuff necessary to get toys approved.

At the other end of the market are the maker-ish households where someone's built a DIY 3D printer. These are, generally speaking, lower-res than anything you'd see in a toy shop today (though I recently got a preview of the next generation and, hoo-boy, it's pretty tastily high-res!), but they have the advantage of being present in homes where parents might print the toys themselves, assuming (Alice hopes) any safety liability.

Alice has been thinking hard about how to make a game that uses mecha-like toy parts you print yourself and also trying to figure out how she'd make any money off it. I'm pretty sure there's an opportunity there somewhere, and it's awfully fun watching Alice and her business partners try to find it.

+ For an extended version of this column, visit makezine.com/28/doctorow.

Cory Doctorow's latest novel is *Makers* (Tor Books U.S., HarperVoyager U.K.). He lives in London and co-edits the website Boing Boing.

makielab.com

Maker

BALSA DREAMS

Paul K. Guillow's model airplanes have been buzzing over parks since 1926.

By Andrew Leonard

"This is pretty cool," my 13-year-old son, Eli, admitted, as we waited for the glue to dry on the wing of a Cessna 150 balsa wood model airplane. I couldn't disagree.

Way back in the last century, when I was 13, I devoted many happy hours to building scale model "stick and tissue" airplanes — Sopwith Camels, Fokker D.VIIs, P-51 Mustangs, and Mitsubishi Zeros. To see my son groove to the simple pleasures of balsa wood construction struck a familiar chord. Snapping together the plastic parts of a sci-fi Japanese robot is fun; building a wood-and-paper plane that can fly generates a higher class of satisfaction.

My son's interest in the Cessna was all the more rewarding when I considered that, as a kid in the early 1970s, we didn't have Xbox 360s or Angry Birds or all the Japanese anime we could stream from Netflix to while away the hours. My son's generation enjoys unlimited access to the most immersive, distracting, and addictive digital entertainment options the human mind has ever devised. But there he was with a sanding block in his hand, carefully smoothing out fuselage joins — and enjoying it!

Time froze as we stood in front of my basement workbench. We were using the same set of X-Acto knives my grandfather gave me for my 11th or 12th birthday. Our Cessna came from a kit made by Guillow's — the same company that manufactured all the airplane models I put together as a boy. When I examined the construction plan, I noticed that the copyright date was 1971, and it occurred to me that I had hunched my back over the identical plan three and a half decades earlier.

The die-cut balsa wood part sheets were also intimately familiar — for all I could tell, they had been crunched out by the very same machines in use 35 years earlier. When I clumsily snapped a wing former out of its sheet and accidently broke it, the déjà vu feeling was as strong as the smell of the airplane "dope" that modelers use to stiffen the tissue covering the wings and fuselage. I convinced myself I could recall breaking that same piece, long ago.

Andrew Leonard (andrew.leonard@gmail.com) is a staff writer at *Salon*. He lives in Berkeley, Calif., and is still cleaning the glue off his fingers.

Jen Siska

MODEL RELATIONSHIP Andrew Leonard admires the first wooden model airplane that his 13-year-old son, Eli, made. Today they build balsa airplane kits together.

Courtesy of Guillow's

BUT HOW WAS THIS POSSIBLE? THE striking fidelity with my memories suggested Guillow's stagnation, if not terminal decline. I conjured up a grim globalization scenario, imagining that a giant toy multinational had long ago scooped up Guillow's and moved its manufacturing plant to China or some other cheap-labor locale. What else could explain such stasis?

I could not have been more wrong. Curiosity piqued, I soon learned that while the golden age of the model airplane hobbyist scene belongs to the distant past, and nearly all the competitors that Guillow's battled for market share in the 1930s, 40s, and 50s are as dead as the dinosaurs, Guillow's is still independently operated and chugging forward. Remarkably, the firm still operates in the same Wakefield, Mass., warehouse complex that Paul K. Guillow, its eponymous founder and World War I Navy aviator, moved into back in 1933.

After digging deeper, I realized I was also wrong to create such a strong dichotomy in my mind between the visceral pleasures of glue and the digital distractions of the 21st century. Guillow's isn't frozen in time — it continues to roll out new model kits and modernize its own manufacturing technology in ways that serve its customers while staying true to the past.

And can there be little doubt that the internet is a hobbyist's best friend? As any amateur who has struggled with the sometimes opaque instructions of a Guillow's kit will recall, building a balsa wood model airplane can be enormously frustrating.

And that, I believe, is why God invented YouTube.

The Guillow Legacy

In 1926, Guillow capitalized on his experience as a Navy pilot by creating, in the barn of his family home in Wakefield, a line of simple balsa wood construction kits based on World War I combat aircraft that retailed for the backbreaking price of 10 cents each. His timing could not have been more perfect. Charles Lindbergh's successful 1927 cross-Atlantic solo flight in *The Spirit of St. Louis* ignited a national aviation obsession — what one historian of the model airplane industry excitedly described as "the greatest torrent of mass emotion ever witnessed in human history." A score of model airplane kit makers popped up to feed an insatiable hunger born from the romance and futuristic promise of air flight.

Guillow died in 1951, at just about the same time the balsa wood stick-and-tissue hobbyist sector began a long decline (pick your own reason: the rise of plastic, the emergence of TV, the ascendance of Lego). But his wife, Gertrude, kept the company going while other model makers fizzled out.

A key explanation for the company's survival, says current president Tom Barker, who has been with Guillow's for 35 years, is

FANTASTIC FLIGHT

(Left) In 1926 World War I Navy aviator Paul K. Guillow began selling combat aircraft balsa kits that he manufactured in his barn.

(Opposite) Many of Guillow's kits that were introduced decades ago are still available. Today, many of the balsa wood components are laser cut, meaning broken pieces are a thing of the past. "They almost fall out," says Guillow's designer Mark Tennant.

(Above) 1:20 scale model of the 1903 Wright Flyer.

a policy of diversification. Only about 30% of the company's $5–$6 million in annual revenue comes from the scale model construction kits. A larger share, 40%, is generated by the sale of simple balsa wood gliders constructed from just two or three pieces and retailing for a couple of bucks. Another 30% comes from promotional business: cheap balsa flying toys that sport individualized company brands. "We've got everything down to a science," says Barker. "We've been doing the same thing for a long time."

But Guillow's isn't standing still. Senior designer Mark Tennant says the company routinely rolls out new kits — most recently, a scale model Wright Flyer. Tennant says the increasing popularity of cheap and light radio-control technology has inspired the company to figure out ways to design its models to accommodate modern electronics.

The company is also gradually phasing out its old die presses, cumbersome machines that have been chomping on balsa wood for 40 years or more. Eventually, says Tennant, all the part sheets for scale models will be laser cut — a shift that vastly simplifies the design and production of new models and also enhances the user experience. No more broken balsa parts! "They almost fall out," says Tennant. "It's a night and day difference."

Old School, New School

No more broken pieces? The notion initially struck me as sacrilege that broke the covenant connecting my present-day experience with my son to my past incarnation as a preteen modeler. If you aren't forced to jury-rig a solution to a piece of broken balsa wood, or discover for yourself that gluing together two pieces of balsa wood creates a join that can be stronger than the wood itself, what's the point? If your son isn't shivering in nervous tension as he attempts to free his own parts from the sheet, where's the challenge? Lasers? Bah, humbug! But as my son and I continued building our model and I started researching this story, I realized that drawing a firm line between old-school purity and the age of digital simulacra wasn't as cut-and-dried as I initially surmised. Where would today's hobbyist be, for instance, without the web?

Back when I was 12 years old and working on my Guillow's kits, I felt completely on my own. I had to decide for myself how to interpret the often-cryptic instructions, depending on my own ingenuity and plenty of wasteful trial and error.

I'm sure there were hobbyist clubs in New York at the time that I could have tapped for information — although not as many as flourished in the 1930s and 40s — but I was a pretty shy kid, and that wasn't my scene. So I ignored stuff I didn't understand and made horrible mistakes. I once botched up the process of covering my model with tissue so badly I had to junk the whole kit and start over. And then there's the day I took my Fokker D.VII out for a spin in Manhattan's Central Park to test out its rubber-band propulsion system and crashed my pride and joy straight into a tree. A tragedy beyond belief. Balsa wood is gloriously light — and terribly fragile.

My son, however, not only has the benefit of what I remember of my hard-won experience, but everyone else's as well. He's a member of a generation whose first step to solving just about any problem is checking YouTube for a tutorial.

As Barker told me, the internet does a fabulous job of providing tech support that his 45-person company simply isn't equipped to handle. You want to talk about the physical and chemical properties of wood glue? It's online. Curious as to the best strategy for properly bending piano wire into landing gear? The hard part is picking which tutorial to follow. Your local hobby shop has closed? There's a wider selection of everything available online than any hobby store was ever able to offer.

So even as Eli and I built a connection to generations of hobbyists before, I felt a great sense of relief in knowing that, were we to become baffled at how to proceed, we knew exactly what to do — log on!

And that digital boon stretches far beyond materials and techniques, it also helps expand and deepen our own grasp of history. In 1973, I didn't have a clue that long before Guillow's established its dominance over the balsa wood model scene, an outfit called the Cleveland Model and Supply Company reigned supreme as the ultimate provider of detailed, ultra-accurate, ultra-challenging kits.

Today, after reviewing photographs and analyses of every model in the Cleveland catalog, I can bid for intact 50-year-old Cleveland kits on eBay. I can review, via Google Books, ads for Guillow's models published in issues of *Boys' Life* from the 1960s or marvel at a collection of 40 years of beautifully illustrated covers of the periodical *Model Airplane News*. In short, my son and I could connect with the whole universe of model airplane hobbyists, breaching the annoying physical restrictions of space and time.

Thanks to the internet, I was even able to get my hands on a yellowing copy of *Building an Airplane* — an illustrated guide to balsa wood model construction written by Guillow and published in 1943. "Just Follow the Pictures," says the friendly looking, disembodied head of a man in aviator goggles and leather flying cap.

I was particularly struck by the fifth page: "Tools and Materials." There's a drawing of the "strip stock" — the slab of "stringers" that serve as the raw material for wing struts and the fuselage frame. It is identical to the strip stock included in my Cessna kit 70 years later. A sketch of the "print board" looks remarkably similar

QUALITY TIME

Leonard and Eli making a Cessna 150 balsa wood model airplane from a Guillow's kit. Leonard says YouTube is a terrific resource for answering tricky build questions. "I felt a great sense of relief in knowing that, were we to become baffled at how to proceed, we knew exactly what to do — log on!"

Jen Siska

to the sheets of parts in modern Guillow's kits, but note the instructions: "Cut out the parts from the printed sheet with a razor blade." This booklet predated the widespread use of die-cutting.

There's also a recommended tool not yet part of my arsenal — a miniature coping saw useful for such tasks as carving small blocks of wood into the shape of a nose cowl. Talk about old school! As a 13-year-old, I might have been intimidated, but today, if there isn't already a coping saw/nose cowl tutorial on the web, there will be one soon.

A laptop at one end of the workbench, Guillow's *Building an Airplane* at the other, my son standing with me in the middle, messing around with glue and X-Acto knives, while the entire internet cheers us on. Has there ever been a better time to build a balsa wood model airplane? I don't think so.

More photos of the Leonards and their Guillow's: makezine.com/28/guillow.

FREE! INSIDE!

SCIENCE IN YOUR CEREAL BOWL!

These famous cereal premiums were tiny — but packed with mighty scientific principles!

By Bob Knetzger

Cereal manufacturers learned early on that an inexpensive giveaway inside a box of cereal could inspire a purchase and create brand loyalty with moms and kids. From the 1950s on, the cereal aisle in the grocery store became a mini toy shop with an endless array of plastic baubles, punch-out character masks, and collectible trinkets. Amid the secret decoder rings and cowboy sheriff badges were some cleverly designed toys that ingeniously used scientific principles to amaze and entertain.

Here's a look at six classic cereal premiums that built inquisitive young minds.

1. Bo'sun Whistle

How did a simple cereal-prize whistle empower an early phone-phreaking hacker and inspire the founders of Apple Computer? Starting in the mid-1960s, Quaker Oats packed free Bo'sun Whistles inside boxes of Cap'n Crunch cereal. This plastic giveaway produced a piercing two-toned blast that (like a real bosun's whistle) could be heard over the sounds of the sea or in bad weather.

Coincidentally, the whistle's perfectly pitched 2,600Hz tone could also be heard by AT&T's analog telephone trunk line-switching circuits. Tricking the billing circuits resulted in

Bob Knetzger

SQUEAKS AND SQUEEZES

(Opposite) Cap'n Crunch's whistle, with its 2,600Hz squeal, became a favorite tool for phone system hackers.

(This page) How do you control Diving Tony? Only you (and millions of other kids of the 1980s) know the secret.

free (well, stolen) long distance phone calls. Phone phreaker and computer programmer John Draper, nicknamed "Captain Crunch" for infamously demonstrating this slick whistle trick, went on to develop electronic tone-generating circuits to do the same thing.

Draper's technical skills impressed a young Steve Wozniak, who hired him to create circuits for Apple Computer. Unfortunately, publicity from a magazine article "blew the whistle" on Draper, and he was convicted on toll fraud charges. He wrote the first word processing software for the Apple II while in "the brig." Today's digital phone circuits are unaffected by these nautical noisemakers.

2. Diving Tony

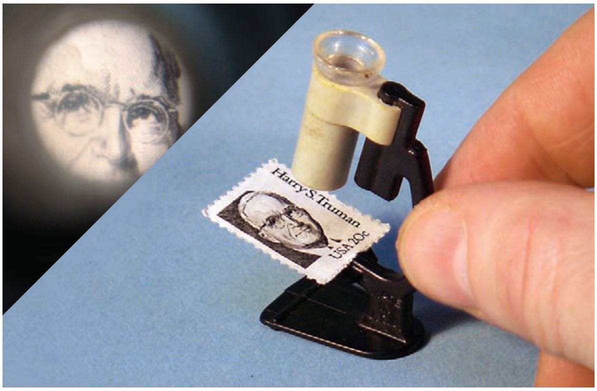
Kellogg's Frosted Flakes featured Diving Tony, a witty 1980s remake of a classic scientific toy, the Cartesian diver (named for the 17th-century French philosopher René Descartes). This miniature version of Tony the Tiger mysteriously obeyed your commands, diving and rising inside a water-filled plastic soda bottle. Gr-r-reat! — but how did it work?

The scientific secret used the incompressibility of water along with the ideal gas law: the volume of a gas is inversely proportionate to the pressure on it. The plastic Tony was molded to be neutrally buoyant and float near the top of the bottle. When you squeezed the bottle, the pressure on the water compressed the air bubble inside Tony. The reduced bubble displaced less water, making Tony less buoyant, and he sunk to the bottom.

When you released the pressure, the bubble expanded and displaced more water, so Tony became buoyant again and rose back up. Because you couldn't see the bottle being squeezed, the up and down diving action seemed magical!

3. Balloon-Powered Toys

There were many balloon-powered cereal toys, but they all obeyed Newton's third law, about the mutual forces of action and reaction between two bodies. The force created by a jet of air escaping from a rubber balloon



SCOOTERS, SCOPES, AND SUBS

(Above) Balloon-powered racers were found in many brands of cereals.

(Left) This Wheaties prize was the mini-microscope of champions.

(Opposite, top) Quispmobiles were powered by flywheels.

(Opposite, bottom) This submarine used baking powder to surface and dive in the sink or bathtub.

was powerful enough to propel a toy car in the opposite direction.

As early as 1950, Kellogg's offered a Jet-Drive Whistle Loco, available by mail for 25 cents and a box top from Kellogg's Corn Flakes. According to the promotional literature at the time, the 4"-long injection-molded plastic steam locomotive was "accurately scaled — even the rivets show." The corny sales pitch to grocers touted: "All steamed up and ready to go! Get aboard — here's your ticket to biggest sales yet. Is there a kid in America who wouldn't want one?" Only the mailman knew for sure.

This science-based gimmick is an irresistible force that kept coming back. In 1961, Nabisco's Rice and Wheat Honeys cereals came with updated Racing Robot and Speeding Spaceman variations. By the 1970s, Quaker Oats included its own version: Balloon Racers, free inside boxes of Cap'n Crunch-brand cereals.

The more compact 2½" design kept plastic costs down and — thanks to Newton's second law, force = mass × acceleration — kept car speeds up. With less mass, these smaller cars featuring the Cap'n, Jean LaFoote, and Smedley (the Peanut Butter Crunch elephant) went even faster on the same balloon power.

4. Optical Toys

The science of optics has also proved to be a popular platform for premiums. Periscopes, spyglasses, and lenticular lens "wiggle pictures" have all been offered as fun freebies. You almost need a real magnifying glass just to see the Wheaties Microscope, a real working mini-microscope, offered free in cereal boxes starting in the 1950s. More of a miniature magnifying glass, the single plastic lens in an adjustable eyepiece tube afforded very limited magnification and plenty of optical distortion — but it really worked!

5. Kinetic Energy Toys

The science behind even the simplest toy top or yo-yo could make your head spin. The kinetic energy of a flywheel is described by

the formula $E_k = \frac{1}{2} I\omega^2$, where E is the amount of kinetic energy, ω is the angular velocity (how fast it's spinning), and I is the moment of inertia (resistance to change in spin). To find the moment of inertia for a disk with a large center hole, just use $I = \frac{1}{2} m(r_1^2 + r_2^2)$. Got that?

Fortunately no math skills were required to have fun with the Gyro-Cycle or Flywheel Car premiums in Quisp cereal from Quaker Oats, which originally landed on shelves in 1965. One tug of the rack-and-pinion geared pull strip and the mini-flywheel instantly revved up to high speed (plenty of ω!). The clever design also included a metal disk in the flywheel (much more mass than a plastic one) for increased I. All that ω and I resulted in enough kinetic energy to send Quisp, the spin-powered spaceman, quickly zipping across the floor.

6. Baking Powder Power!

One classic cereal toy has stayed crunchy in the milk of time for over 50 years: the baking

HEY KIDS! Now you can make your own version of the famous diving sub! No box tops needed — just flip to page 164 of MAKE Volume 26. "Toy Inventor's Notebook" shows how to make your own working version of the diving sub from a potato: a Diving SpudMarine!

powder-powered diving sub. In 1955, boxes of Kellogg's Rice Krispies promised "FREE INSIDE! An actual working ATOM SUB!" In reality, a simple kitchen chemical reaction provided the fuel for millions of these miniature marvels. A pinch of baking powder from mom's pantry contained both an alkaline, sodium bicarbonate ($NaHCO_3$); and an acid, cream of tartar (potassium bitartrate, $KC_4H_5O_6$). When combined in water, the two react:

$$NaHCO_3 + KHC_4H_4O_6 \rightarrow KNaC_4H_4O_6 + H_2O + CO_2$$

producing a salt, water, and carbon dioxide gas, CO_2. In recipes, the CO_2 makes quick breads and muffins rise. In this case, the CO_2 makes toy submarines rise. The buoyant force of the bubbles formed is enough to lift the submerged sub. When it surfaces, the sub tips to one side, the bubbles are released, the sub sinks, and the cycle repeats.

Over the years, there have been many versions of this buoyant bubbling toy: submarines, diving frogmen in assorted sizes, killer whales, sharks, and mechanical monsters. And though the most famous was the 1955 submarine design, a patent search finds a design dating from 1920. Who knows how many other versions are floating around?

Bob Knetzger is an inventor/designer with 30 years' experience making all kinds of toys and other fun stuff.

STRUMMING UP A BUSINESS

How a kids' bike inspired the creation of a cool new guitar kit.

By Rafael Atijas

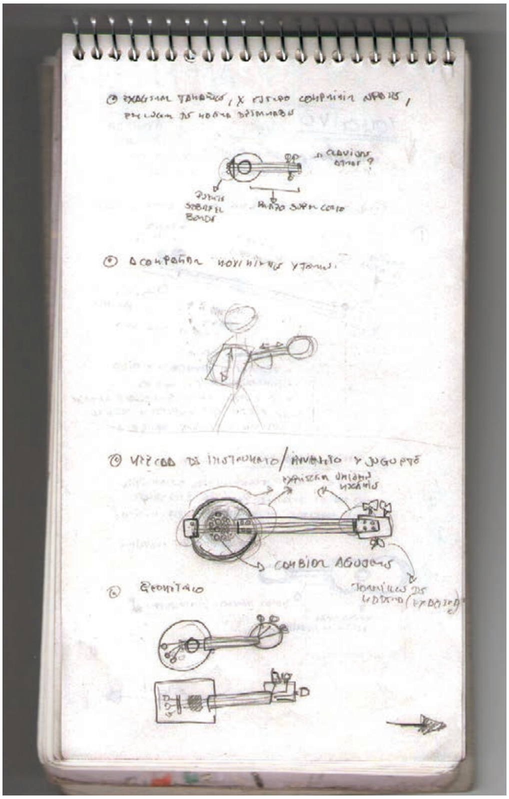
It was out of pressure that I came up with the idea of building a three-string guitar for kids and parents to build at home. I was completing a master's in integrated marketing at New York University, and for the thesis I had to write a business plan for a company I had to invent. And that was really it. An idea on a piece of paper.

How I came up with the idea is still a mystery to me, but it's no surprise that I narrowed it down to something music-related, as that's my passion. I guess I tied music with trends I saw around (I'm a marketer after all): the need for simple, functional design; the DIY movement; parents' obsession for products that enhance their kids' abilities; the customization of products; and sustainability. The fact that most kids' guitars suck also made it easy for me to realize there was an opportunity here.

So I set out to design and make a guitar for kids that was different from other guitars out there. A guitar with a design appealing to both children and adults that would allow them to share the experience together. Above all, I wanted to design a guitar that made it easy and fun to play music.

All of these concepts led to the defining

Sebastián Ribeiro



Fernando Blanco (right)

characteristics of the Loog Guitar. It comes unassembled in kits and has just three strings, with assembly and playing instructions available online. Cigar box guitars were an inevitable reference. In my eyes, cigar box guitars offer a very real do-it-yourself experience. I thought it would be stupid to compete with that because the plan was to bring innovation to the children's guitars category, not to copy an already amazing instrument.

Instead, I took more inspiration from the LikeABike kids' bicycle (likeabikeusa.com). I wanted to make a line of guitars that had an elegant, minimal design and were made of sustainable woods. I made the decision to scale back the DIY factor and make Loogs extremely simple to build. Something that could be done in 15 minutes and didn't involve glue or sandpaper: just screw a few parts together and that's it.

Because I'm not a trained designer, I knew I had to team up with someone who could bring my ideas from napkin drawings to proper CAD plans, and I found the ideal partners in Lucía Guidali, Agustín Menini, and Carlo Nicola — three industrial designers from Uruguay, my home country, who work together under the name of Colectivo Disán. They had no experience in building guitars, but they're very talented and had experience designing children's products and working with sustainable woods. It ended up being a ten-month collaboration process, and after countless design iterations, we finally arrived at what you now see on loogguitars.com.

Along the way we brought a luthier into the process, the talented Ariel Ameijenda, who helped us adjust a few design decisions: to make sure the guitar tuned correctly and that the neck would support the right amount of pressure, and to address other technicalities.

CONCEPT TO CREATION

(Opposite) Loog Guitars founder Rafael Atijas assembling a guitar kit.

(Left) Atijas' notepad with early sketches.

(Right) Assembled Loog I guitar with swappable pickguard, on a cardboard Loog stand.

MAKER MADE

(Clockwise from top left) The mold for the Loog III guitar body; bodies waiting to be varnished; the three Loog models are I (rectangular), II (double cutaway), and III (triangular); Loog necks come in two sizes: a short-scale neck suitable for kids younger than 9, and a longer one for older kids.

Ariel was also in charge of building the first prototype. It was an absolute joy to put the parts together for the first time, string the guitar, and start playing music.

And, because we wanted to make the guitar parts compatible with all models so kids can mix and match (for example, they can buy a rectangular guitar and use it with a triangular body if they want a new guitar without having to buy a whole new instrument), we also knew right away that the guitars would have to be made through an industrial process and that we'd have to build molds and use CNC machining.

We took the project to a few guitar factories in the United States, but they simply weren't interested. We also tried options in Uruguay, Brazil, and Argentina, but it was just as difficult there to get a manufacturing partner involved with the project. We ended up — where else — in China, which is crazy because Loog Guitars is still a very small project.

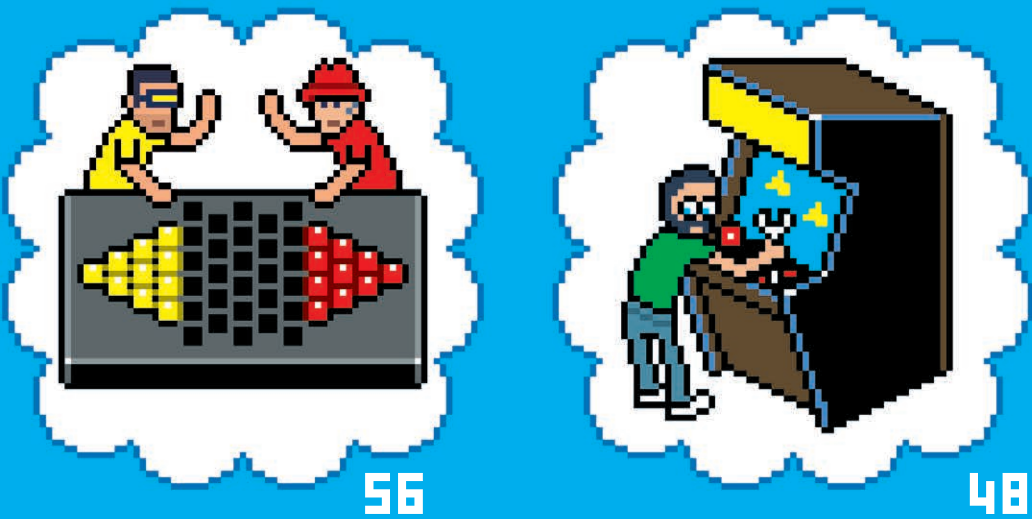
Fortunately, the alignment of the guitar gods (and a quick search at alibaba.com) helped us come across a small family-owned factory, which I visited last March. Now — thanks to the backing of 440 strangers who saw Loog Guitars on Kickstarter, believed in the project, and wanted to play a part in bringing the idea to life — Loog Guitars are in production!

The whole Kickstarter experience and how it ties to this new maker phenomenon really blew my mind. Coupled with the fact that some random guy from Uruguay can start a business in the U.S., manufacture in China, and do it all from an old MacBook from the nearest free wi-fi cafe, it seems pretty obvious and exciting to me that we're in the midst of a new makers' revolution.

Rafael Atijas (ratijas@loogguitars.com) is the founder and CEO of Loog Guitars. He has a master's degree in integrated marketing from New York University, where he graduated with honors in 2010. Rafael lives in Montevideo, Uruguay, but finds every imaginable excuse to go back to New York as often as he can.

Rafael Atijas, Fernando Blanco (models)

TOYS AND GAMES



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Emulate the raw fun of classic arcade games, wirelessly on your TV.

BY JOHN BAICHTAL AND ADAM WOLF

Do you remember those classic video game arcades filled with rattling quarters, 8-bit songs, and flashing lights? You can reclaim that excitement in your own living room with this Coffee Table MAME Console.

In 1997, Italian software developer Nicola Salmoria released the first iteration of MAME (Multiple Arcade Machine Emulator), a free software platform that lets standard PCs play classic arcade video games. Since then, other emulators (sometimes incorrectly called MAMEs) have come out for old game consoles like Super NES, ColecoVision, PlayStation, and others. For each of these emulators, countless game programs, or game ROMs, are widely available.

This means anyone with a computer can play a plethora of classic old video games, which is great. But the hard(ware) reality is, these timeless challenges, which fuse bare-essential graphics with great 8-bit soundtracks, just aren't as fun with delicate controls like keyboards, mice, or trackpads. Arcade games were designed for button-pounding, joystick-jamming physical action.

Oftentimes makers will build MAME cabinets that resemble old-time arcade games, but ultimately they're just PCs with buttons and joysticks wired in. With the Coffee Table MAME Console, we're going to build a stripped-down version of the arcade machine. It doesn't need a monitor because you can use your TV, and instead of having the computer inside the enclosure, the console connects to your PC via Bluetooth.

We used MicroRAX aluminum beams to build our enclosure, with black-painted plywood for the base. And we didn't want just a boring box, so we sexed up the console with a sheet of clear acrylic for the top and red and blue LEDs that display random patterns of flashes. Every time you toggle a joystick or button, you cycle to the next LED pattern, so the lights dance while you play games.

Cody Pickens

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MATERIALS

For the MAME:

TV with an open VGA or HDMI port
Computer, Bluetooth-enabled, with VGA or HDMI video port
Video cable, VGA or HDMI to connect to TV
Arduino Mega 2560 part #MKSP5 from Maker Shed, makershed.com
Bluetooth Arcade Controller Shield for Arduino, from Wayne and Layne Maker Shed #MKWL05. Or you can use a WT12 module, a WT12 Bluetooth breakout board, and an LM1117 3.3V voltage regulator.
Arcade joysticks, classic style (on/off, not variably sensitive), 8-way to 4-way switchable (2)
Arcade buttons, classic style (13) We used Sanwa OBSF-24 buttons.
Spade connectors, to fit joysticks and buttons (42) two ⅛" for each button and eight ¼" for each joystick. Most arcade controls use ¼" connectors, but our Sanwa buttons needed ⅛".
Battery holder, 3×AA, with built-in switch
LEDs (8), any colors for decorative blinkenlights. We used 4 red, 4 blue.
Resistors, one for each LED, matched to LED forward voltage and current refer to ledcalc.com. We used 330Ω for our red LEDs and 80Ω for blue.
Hookup wire
Heat-shrink tubing

For the enclosure:

MicroRAX aluminum beams: 900mm (2); 260mm (4); 50mm (8) MicroRAX beams are 10mm×10mm and 900mm standard length; you can order custom lengths (metric dimensions) or cut them yourself. They're also available in kits, which include many of the items listed here.
MicroRAX nut plates, 2 packages (20 per package) for use with 5mm machine screws and screws attaching acrylic top to frame
MicroRAX joining plates, L-style (16)
MicroRAX joining brackets, 90° (8)
Plywood or MDF, ⅜" thick, at least 11"×35½" for the base
Acrylic, clear (plexiglass), ¼" thick, at least 11"×35½" for the top
Machine screws, M3, 5mm long, with matching washers (72) available from MicroRAX, used with joining plates and brackets
Machine screws, M3, around 8mm long, with matching washers (16) 12 to attach acrylic top to frame and 4 to anchor joysticks to acrylic top. I used 10mm machine screws and had to grind them down 3mm to work; you can try to find better-sized screws.
Wood screws, #8×⅜", pan-head (8) to attach joining brackets to base
Wood screws, ½" or ¾" (5)
Zip ties and small screw eyes (optional) for organizing wires
Rubber feet (4)
Spray paint We used black.

TOOLS

Drill press or cordless drill
Drill bits for screws in Materials list
Hole saw(s) that works with plastic, to cut button and joystick mount holes. Ours were 30mm but others need 1⅛".
Soldering equipment and solder
Hacksaw for cutting aluminum beams
Handsaw or table saw with carbide blade (optional) for cutting acrylic sheet and/or plywood/MDF base
Programming cable for Arduino

START

1. ASSEMBLE THE ENCLOSURE.

There's no set size for the console — go with whatever seems right and suits your needs. We started by making a rectangular MicroRAX frame 900mm long (the default length of the MicroRAX beams, or around 35½") by 280mm (11"), and with eight 50mm (2") legs (Figure A).

For the base underneath, we painted a sheet of plywood black, then attached our MicroRAX framework onto it with #8 wood screws. Cut the acrylic to the same size as the plywood, but don't attach it yet. Install 4 rubber feet (one for each corner) under the base; these will prevent the console from slipping during heated gameplay.

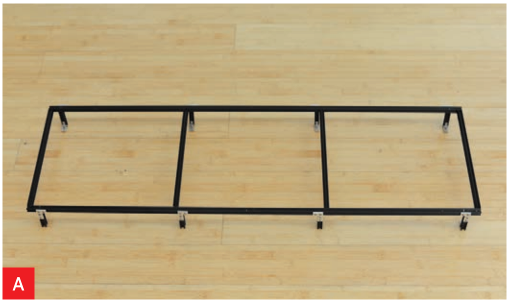
We designed our console to rest on a coffee table, but you can make yours however you want — it doesn't even have to look like a console. For instance, you could wire a joystick and buttons into the arm of a recliner.

2. ADD THE ARCADE CONTROLS.

Cut holes in the acrylic corresponding to the arcade controls and pop them in. Wire the positive leads to any of the Mega's digital inputs, except pins 0, 1, 13, 18, and 19. Connect ground wires to the negative terminals (Figure B).

3. CONNECT THE ARDUINO AND ARCADE CONTROLLER.

The Bluetooth Arcade Controller Shield works as an interface between the PC on one side and the Arduino and controls on the other. There are numerous good MAME controllers, but we chose a Bluetooth solution because it lets the console work wirelessly, untethered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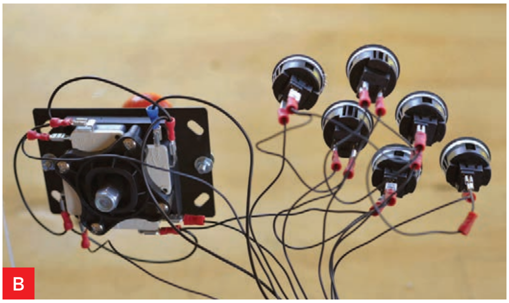
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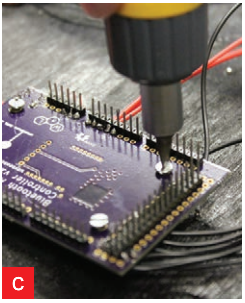
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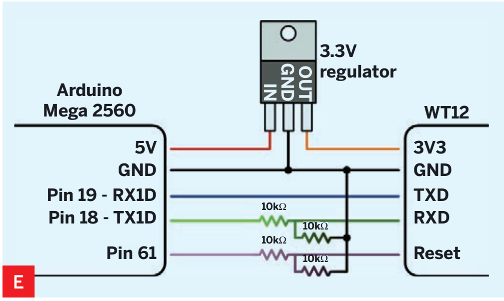

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from computer or TV. To the PC, the controller looks like a Bluetooth keyboard. To the Arduino, it's just another serial device.

The Bluetooth shield plugs onto the Arduino. We attached our Arduino and shield upside down near the center of the base, with the shield screwed to the wood through its 4 mounting holes and the Arduino plugged in on top (Figures C and D). With so many wires connected to the shield, this prevented solder joints from wiggling and breaking.

If you don't want to buy this controller, go ahead and build your own! You just need a WT12 Bluetooth breakout board, an LM1117 3.3V voltage regulator, some jumpers, and a bit of perf board. Figure E shows how to wire these components together to the Arduino Mega's transmit and receive pins (pins 18 and 19). With this arrangement you can install the WT12 board and Arduino side by side in your cabinet. This will work just like the Bluetooth shield; it's just not as slick.

4. WIRE UP THE LEDS.

For each LED, solder a resistor to the positive lead, add the 2 leads (Figure F), cover with heat-shrink, and connect the resistor's (+) side to a free I/O pin on your Arduino or Bluetooth Arcade Controller Shield.

You can wire up as many LEDs as you have extra Arduino ports; we went with 8, on ports A0–A7. For the common ground, we connected all the ground wires to a screw installed in the plywood base (Figure G).

5. ORGANIZE THE WIRES.

To make the wires look nice through the clear acrylic top, we bundled them together with zip ties and secured the bundles to eyelets screwed into the base.

6. ADD THE POWER.

Position and mount the battery pack so that you can reach in and change batteries without having to remove the acrylic top. Connect the lead wire to the Vin port on the Arduino and the ground to the common ground. Note that you could also power the console with a

Gregory Hayes (A, B, G); Peter Tirsek (C, D, F) standard Arduino-compatible wall wart.

Finally, drill and mount the acrylic top onto the MicroRAX frame (Figure H).

7. CONFIGURE THE ARDUINO AND COMPUTER.

The Arduino software for the Coffee Table MAME Console (makeprojects.com/v/28) defines which buttons and joystick positions on the console correspond to which keyboard presses. Upload it to the Arduino like any other sketch, via the programming cable.

Link the console to the computer by powering up the console and searching for discoverable devices through the computer's Bluetooth setup. The computer will see the console as a wireless keyboard. Meanwhile, also connect the computer to the TV via VGA or HDMI. (If your PC doesn't use those natively you can buy an adapter.)

Now you need to download and install one or more emulators onto your PC. You run these emulators as applications, and each one has a configuration section where you associate keyboard letters to the physical controls on the console panel, like Up, Down, and Start. We grew up in Nintendo house-holds, so the two we always set up are FCEUX, an NES emulator (Figure I), and ZSNES or SNES9x, which simulate Super Nintendo. On Macs, we've used Nestopia.

If you're using a computer that's more than 4–5 years old, you'll want to download a legacy version of the emulator. Typically, the emulation software is updated to keep up with computer technology, so the latest edition of MAME won't be happy on a slow machine.

Each emulator plays ROMs, which are memory dumps of the individual games. After downloading a ROM, you play the game by opening it from within the emulator. There are many illegal ROMs floating around. Legitimate sites will show proof that their ROMs are licensed by the rights-holders. Alternatively, if you own a physical copy of the game (e.g.

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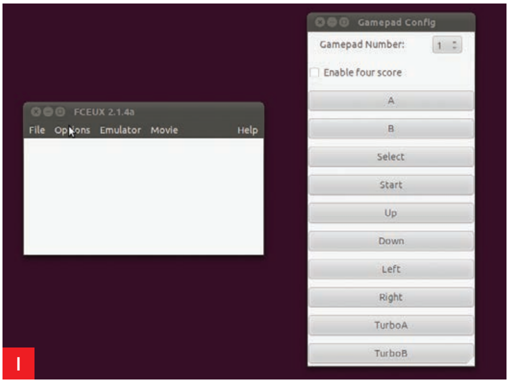

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a cartridge), our understanding is that it's OK to use a ROM for the same title, since keeping a copy for your own purposes is fair use.

The last software component is the front-end, a graphical program that knows about the emulators and ROMs you've installed and organizes and presents them nicely. This is optional, but it's a nice touch. Some even have screenshots and short videos for each game! My personal favorite front-end is Game Launcher, which runs on Linux and Windows.

+ See makeprojects.com/v/28 for project software, schematic, and links to emulator, ROM, front-end, and arcade game-building resources.

John Baichtal is a contributing writer for makezine.com and *Wired*'s geekdad.com. Adam Wolf (feelslikeburning.com) co-founded and co-operates Wayne and Layne, an open source electronics kit business.

Cody Pickens (H)

EYE IN THE SKY

Hack a hobby copter and see what the birds and bugs see.

BY I-WEI HUANG

Mounting a camera on a device that can take you where you can't physically go isn't a new concept. What's new is the size and cost of electronics, and advances in micro radio-controlled flight.

Years ago I bought an Acme FlyCamOne2 video camera, able to capture 640×480 video at 30 frames per second and yet light enough to be carried by a standard R/C helicopter, for around $150. I mounted it on a 400-size helicopter with 30" rotor blades made of carbon fiber and CNC aluminum. Operating at incredible speeds, these are more like flying circular saws than R/C models. The sound alone is terrifying. I was able to record some flights around the park, and even do some stunts like flips, loops, rolls, and inverted hovering, while recording onboard video.

Today you can buy a cheap, no-brand keychain spy camera for about $20. These are less than half the size (a pack of gum) and weight (19 grams) of the FlyCamOne2, so you can fit one in a very small aircraft to record onboard video. Luckily, R/C aircraft technology has also advanced in size, weight, and performance since my last aerial video attempt. Today there are many micro- and sub-micro helicopters on the market, and I've found a perfect-sized R/C helicopter for this tiny camera: the Blade 120 SR from E-flite. It's small enough you can throw it in a backpack, yet big enough to carry the camera without much performance loss.

Sam Murphy

CHOOSING A MICRO COPTER

One of the biggest reasons I picked the Blade 120 SR is that it's a fixed-pitch helicopter. There are two types of single-rotor R/C helicopters: *fixed pitch* (*FP*) and *collective pitch (CP)*. Fixed pitch is exactly how it sounds: the main rotor blades are of a fixed pitch angle, so the amount of lift you can achieve is based solely on how fast the motor is spinning. Much like an electric fan at your house, the faster you make it spin, the more air is pushed out.

In comparison, collective-pitch helicopters have main rotor blades whose pitch is variable, so lift is controlled by changing the pitch angle of the blades, in addition to the RPM of the motor. CP rotor blades can even be negative-pitched — thus the helicopter is capable of flips, rolls, and even upside-down flight. But

MATERIALS

E-flite Blade 120 SR radio-controlled helicopter $160 from horizonhobby.com or other vendors

Keychain video camcorder part #MiniFPVCamera2GB from nitroplanes.com, $23. It's rechargeable via USB, and its 2GB microSD card will hold much more video than the flight time of the helicopter (even when you use 4 batteries and fly them back-to-back like I do). There are better cameras out there, but none this light and small.

Servo tape, double-sided silicone such as Parma Pro or Racers Edge from amainhobbies.com

Cable ties, small aka zip ties

Rakonheli upgrade parts for E-flite Blade 120 SR (optional) I beefed up my copter with CNC aluminum and carbon fiber parts from rakonheli.com: the main frame combo ($61), main rotor hub ($20), swashplate ($24), and flybar ($34).

this extra capability comes with a cost: CP copters are more delicate and much more difficult to fly.

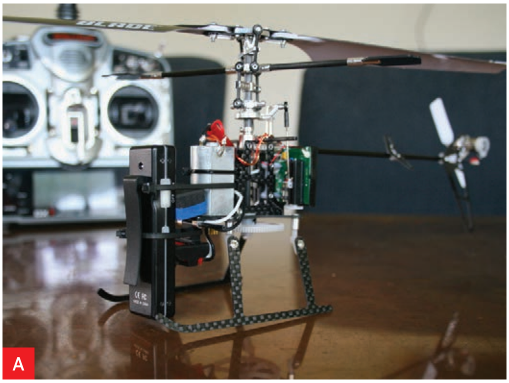
The Blade 120 SR is a very small FP helicopter that's extremely easy to fly. Don't get me wrong, it's not a kid's toy that will fly itself by taking away full control from you. You'll still need to take time to learn how to fly an R/C aircraft, but this one's about as easy as they come for a single-rotor, hobby-level helicopter. It's a well-designed copter that's capable of very precise control and can fly at fast speeds.

Because of its FP nature it's also very crash-resistant, due to its relatively slow rotor speed and light weight. FPs just don't break very easily upon impact as compared to CP helicopters. I've even upgraded mine fully with Rakonheli CNC metal and carbon fiber parts, so it's virtually indestructible.

MOUNTING THE SPY CAMERA

I removed the copter's canopy — luckily with these hobby-grade R/C helicopters, everything is replaceable and easy to remove — then I looked for a good mounting place for the camera.

Usually helicopters fly best if the weight is balanced right on the main rotor shaft. If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I-Wei Huang

extra weight is offset to the center of gravity, the helicopter will be harder to control, and tend to drift in the direction of the heavy end. Even compensating for this electronically and mechanically, it's generally best to have the weight as evenly distributed as possible. However, if you have to pick between being too heavy in the right, left, front, or back, it's best to be front-heavy. Adding 19g may not seem like a lot, but for a helicopter this small, it's a noticeable load.

I settled on the front of the battery mount as the best location, and moved the battery to the back to help balance out the weight.

I applied servo tape to the front of the helicopter, at the battery mount. Then I pressed the camera onto the tape, making sure that it cleared the ground below and the flybar above. Finally, using a little piece of foam for support and vibration dampening, I zip-tied the camera to the main motor at the top, and to the battery mount at the bottom (Figures A and B).

FLYING, SPYING, AND RECOVERING VIDEO

I waited for a calm day to take the helicopter out for a video shoot (it's very sensitive to wind). I flew the copter around the park by my house, successfully threaded between the chains of the swing set several times, and took it up high above the trees. I flew it as high as I could, until I had a really hard time seeing its orientation. My goal was to get a nice aerial shot of my neighborhood landscape; I wanted to see what the birds and bugs see (Figure C).

I also had some fun and flew the helicopter around myself, with the nose of the camera always pointing inward at me, while at the same time an iPhone mounted on my head took video of the helicopter (Figure D). You can see the video at makezine.com/go/videoblade).

Getting the video from the spy camera is easy. You can just use the USB cable (which is also how you charge the battery), or pop out the microSD card and use a card reader. In the end I was very happy with the final results. Of course at this micro size, the camera can be a bit twitchy, but overall the video I recorded was pretty great for a $23 investment.

At the rate these electronics and micro aircraft are getting cheaper, better, smaller, and lighter, it won't be long before you can fit a camera on an even smaller helicopter and have live HD video streaming to your video goggles, at a very cheap price. I am looking forward to that day.

SERVO TAPE AND ZIP TIES

For mounting, I used my two favorite go-to tools of choice for working with small and light electronic projects: servo tape and zip ties.

Silicone servo tape is an amazing product, a thin and rubbery double-sided tape that sticks well to servos or any other plastic or smooth surfaces. I use it consistently to "try things out" before I commit to drilling holes or mounting parts, and often it works so well that it becomes my main method of joining things together. Servo tape can also be temporary — with a bit of prying with a flathead screwdriver, you can separate the parts and clean up the tape residue easily, unlike foam tapes.

I also use zip ties for mounting and testing. I like the tiny ones, because most of the things that I tinker with are fairly small, and you can join them end to end if you need a longer tie. They're incredibly strong and easy to use, but also easy to cut off. Using this combo of servo tape and zip ties, I've made several R/C robotic critters that have been featured on the MAKE blog (blog.makezine.com) and *Make:* television (makezine.tv/episodes/#102), including a flapping fish, a tortoise, and 3-legged SwashBots.

I-Wei Huang is a concept artist and animator working in the video game industry. He is best known for his tinkerings in real, working steam-powered machines and other characterful robots, under the name CrabFu (crabfu.com).

CHINESE CHECKERS FOR TWO

BY CHARLES PLATT

Chinese checkers can be more strategically complex than regular checkers as long as you follow one simple rule: never play against more than one opponent! As soon as three or more people are involved, each becomes a random factor injecting an element of pure chance. I made myself a unique Chinese checkers set for just two people.

The primary challenge in fabricating the board is precision. If the holes are not placed meticulously on a triangular grid, the result will look amateurish.

The overall layout is shown in Figure A. If you have drawing software, your task is simple — just create a bunch of equilateral triangles on your computer and print them. Those who are less well equipped will have to do some measuring.

Suppose you want to space your holes horizontally 1" apart. The next row will be offset horizontally by ½", as shown in Figure B. But how far vertically? Pythagoras provides the answer: the square root of 3, divided by 2. (High-school geometry really can be useful sometimes.) Root 3 over 2 is almost exactly 0.866; and 0.866 times 1" equals 0.866".

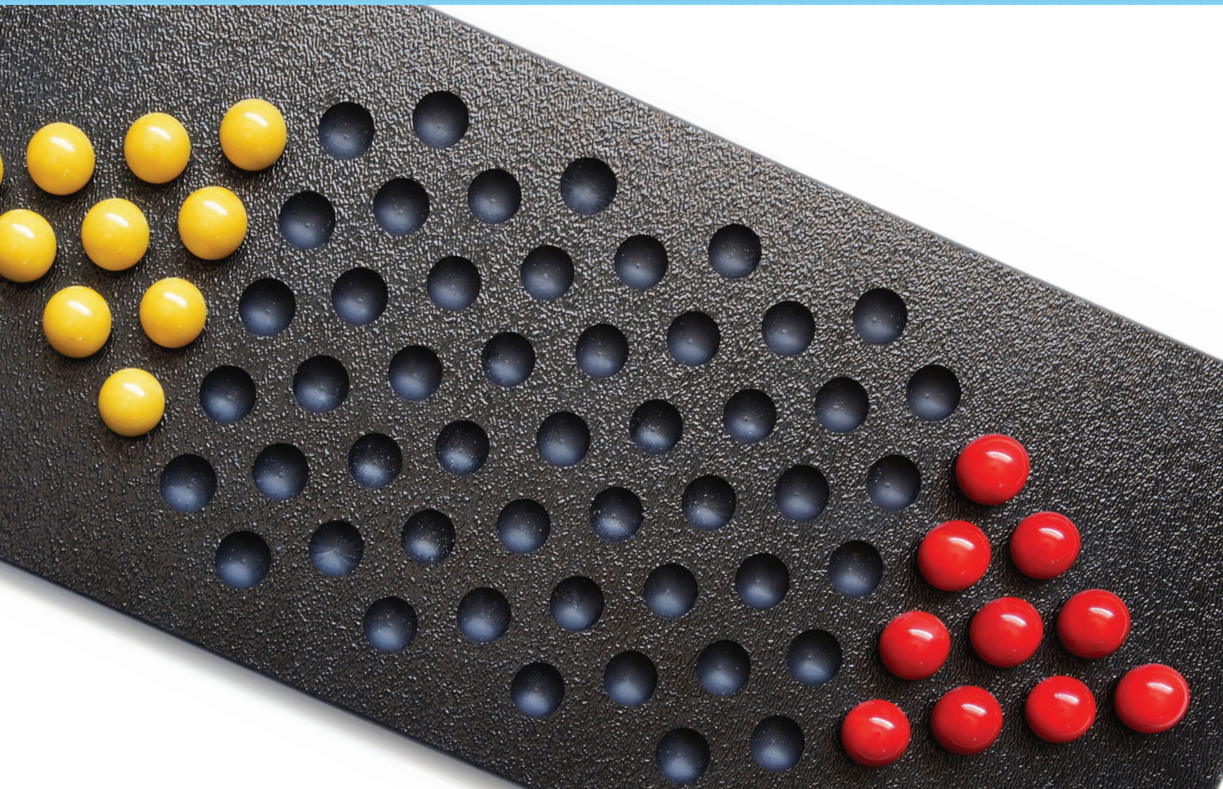
This number can be used as a conversion factor if you want to make the board larger or smaller. For instance, to find the vertical spacing for marble centers ¾" apart, multiply 0.75 by 0.866, and it comes to about 0.65", which is close to 21/32".

Print or draw the layout on a piece of paper and tape it to a rectangle of wood or plastic that you've chosen for the board. It should be at least ¼" thick. Use a sharp, pointed object (preferably steel) to prick through the intersections of your triangular grid into the board. Push the point as deep as you can.

Now remove the paper and select a 3/32" drill bit, which will center itself in the prick marks. Drill no more than ⅛" into the board — if you have a drill press, you can set it to limit the drilling depth; if not, wrap a piece of colored tape around the bit to remind yourself not to drill all the way through.

After you've made the pilot holes, switch to a countersink to widen them while keeping them centered and not going too deep.

Finally, to make elegant marble-shaped dimples, you can use a router bit with a ½" semicircular cutting edge (Figure C). The dimples should be approximately 3/16" deep for marbles 9/16" in diameter, which is the



standard size of Chinese checkers marbles.

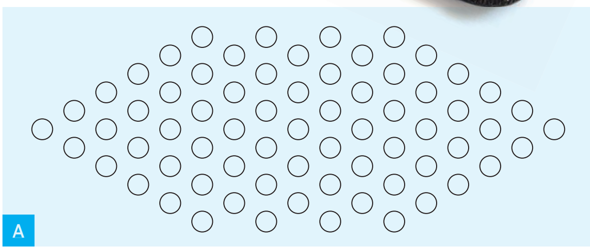
I chose to make my board from ¼" textured ABS plastic, and I finished the edges with a deburring tool. See my article on how to saw, drill, and bend ABS (*MAKE Volume 10, page 100, "Plastic Fantastic Desk Set"*).

As for the marbles, simply search for "Chinese checkers marbles" on eBay or elsewhere online. You should be able to find some for less than $5.

The smaller board is much more portable than the traditional six-player version, and it rouses so much curiosity and comment, you'll never have a shortage of opponents. As for strategy, it's a thought-provoking balance between advancing yourself and blocking your opponent — which is why I find the game more interesting than regular checkers.

Charles Platt is the author of *Make: Electronics*, an introductory guide for all ages. A contributing editor of MAKE, he designs and builds medical equipment prototypes in Arizona.

Charles Platt



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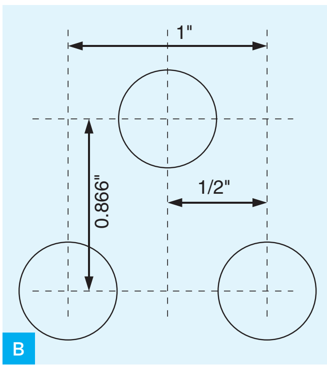

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MASTERING 3D VIEWS

William Gruber put the magic of stereoscopic photos in our hands.

BY BOB KNETZGER

Wouldn't it be fun if you could take your own family pictures in thrilling 3D? That's what William Gruber thought back in 1939. Although stereo photography had been around for years, creating your own 3D photos was more than a little complicated.

It required special cameras and lots of technical know-how to "fuse" together two images to create a deep 3D space. That was fine for hardcore hobbyists, but what about the average person? For them, Gruber cleverly combined several elements to create View-Master, a system for making and viewing 3D photos.

Gruber realized that the then-new Kodachrome 16mm film could be used for more than just movies. The long strip of film could be cut into tiny, individual frames — an economical way to make millions of vibrantly colored transparencies.

Gruber laid out the frames as stereo pairs in a ring around the edge of a flat disc. The intraocular distance (the distance between your eyes) determined the disc's diameter at 3 inches. A disc that size (called a "reel") was just big enough to hold seven pairs of 16mm frames of film. Voilà! The View-Master's sequence of seven images per reel was born.

The first View-Master (V-M) viewer was made of brittle phenolic plastic with a split hinge that opened to change reels. As you pulled down on the lever, the reel swiveled on a center pin, swinging the next image into view with a snappy sound. That "tug, swirl, clack — wow!" is the well-known and beloved V-M 3D viewing experience. (To this day, V-M reels are still made with that same punched center hole, even though it hasn't been used in viewers in the last 60 years! How's that for backward compatibility?)

Forget Grandma's clunky black and white stereopticon cards. With the V-M, everyone could easily view colorful 3D pictures anywhere. V-M went on to make and sell more than 1.5 billion reels with images from around the world — scenic wonders, coronations, animals, fairy tales, and more. Like the ad says, "The breathtaking beauty of View-Master pictures is a new and delightful experience."

But how to take your own 3D V-M pictures? The second part of Gruber's system was the early 1950s-era View-Master Personal Stereo Camera (Figure B). It used Kodachrome slide film for brilliant color and smooth, grain-free

Fig. A: A parade of View-Master viewers (left to right): Model B, 1940s; Model C with light attachment, 1950s; Model D with adjustable focus, 1960s; Model M with push-button advance, 1980s; Model Virtual Viewer with large lenses, 1999–present; and (top) Model L, sold today (with slight variations) as View-Master Classic, 1977–present.
Fig. B: A 1950s magazine ad for the View-Master Personal Stereo Camera.

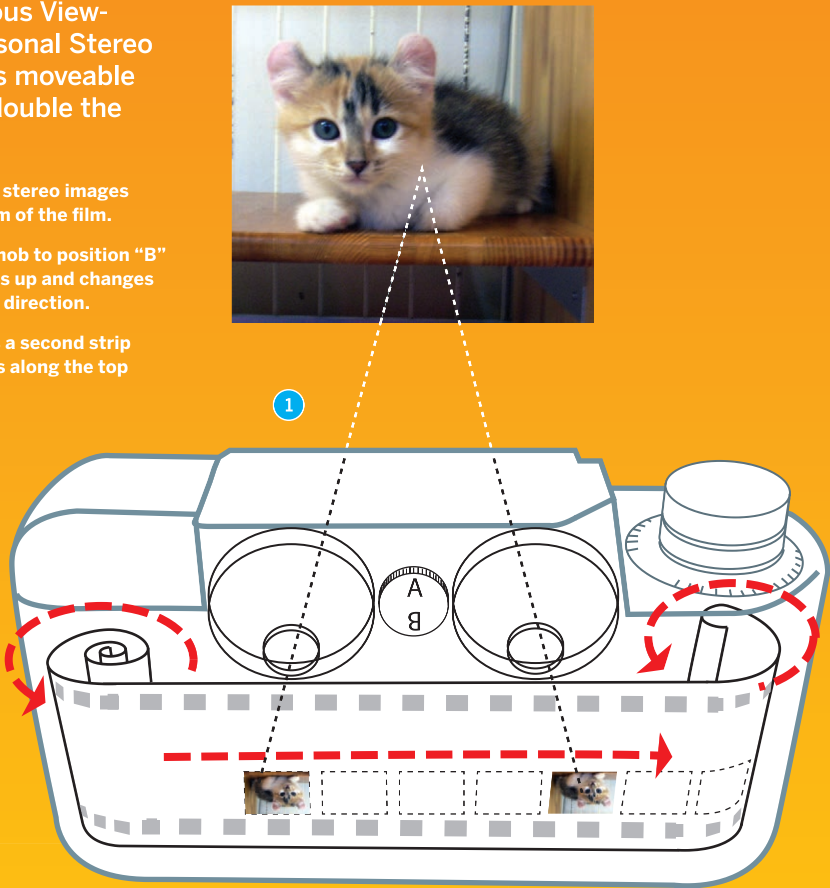
Bob Knetzger

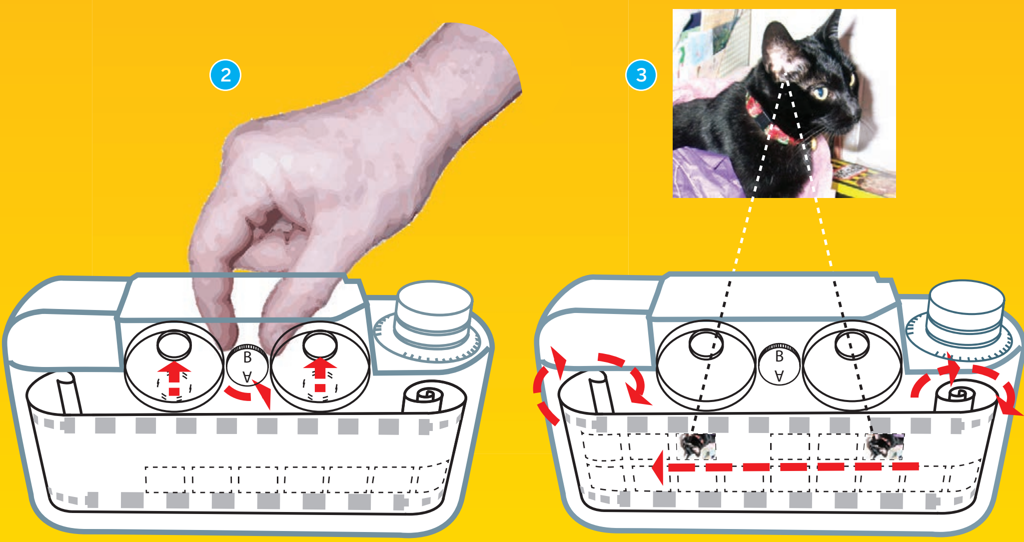
The ingenious View-Master Personal Stereo Camera has moveable lenses for double the pictures!

1. Camera takes stereo images along the bottom of the film.

2. Turning the knob to position “B” moves the lenses up and changes the film winding direction.

3. Camera takes a second strip of stereo images along the top of the film.





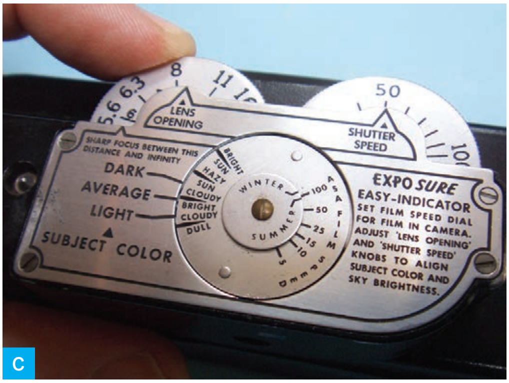


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Fig. C: The Expo-Sure system automatically dials in the matching f-stop and shutter speed settings for you.

Fig. D: Snap on this lens attachment to take "close-up" 3D pictures.

results. But where other stereoscopic cameras took full-frame 35mm images that required complicated mounting (more about that later), the V-M camera created 16mm images to fit the standard V-M reel. That meant only half the width of the 35mm filmstrip was used.

Gruber's "Aha!" moment came when he envisioned running the film through the camera *twice*: once as the film was pulled out of the canister, then again as the film was wound back into the canister. What made it possible was the "Film Miser," an elegant solution with movable lenses.

At the end of the roll you'd simply twist a dial. The swiveling twin lenses would be repositioned from the bottom half of the filmstrip to the top where they would make a second strip of stereo images. Using a 36-exposure roll of film, the Personal Stereo Camera yielded a whopping 69 stereo images. Wow!

With lots of other clever features, the V-M camera was a breeze to use. A bubble level appeared right in the viewfinder to help you hold the camera level. When taking pictures in "you-are-there" 3D, you don't want tilted, seasick-inducing horizons.

Built into the top of the camera was the Expo-Sure, a clever light-metering system (Figure C). First, you'd set the speed of your film (ASA 100 was the top speed setting!) and select the season ("winter" or "summer" lighting). To take a picture, the f-stop and shutter speed control knobs were set to match up the subject color (marked "dark/average/light") to the sky brightness ("bright/sun" through "cloudy/dull"). When you lined up the marks, the f-stop and shutter speed were automatically set for a perfectly exposed picture, no light meter needed.

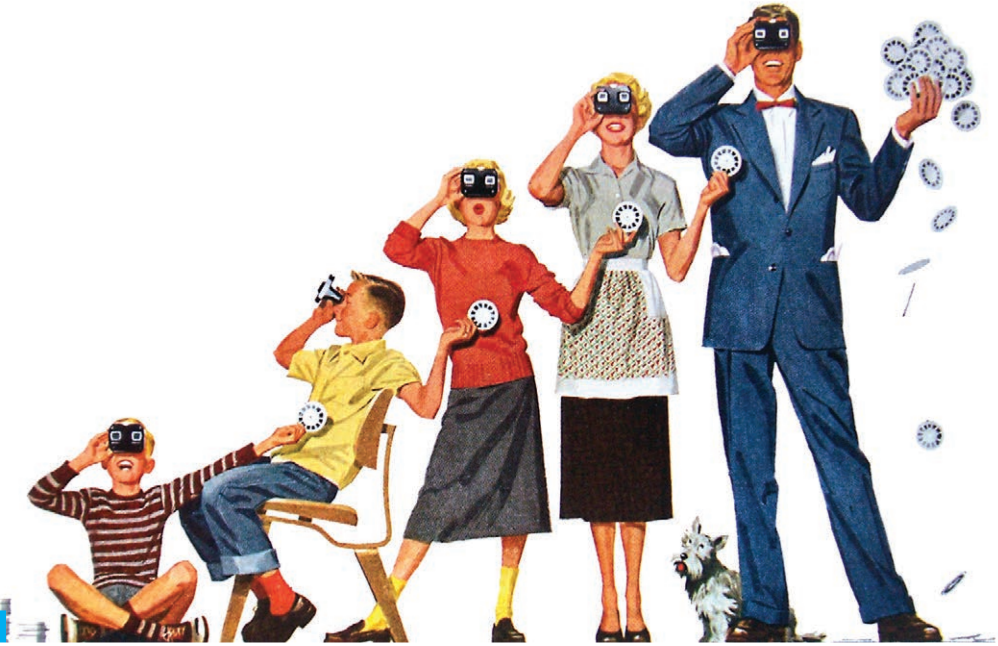
It also indicated the depth of field right on the dial. To get more of the picture in deep focus, you'd simply use a smaller aperture. The Expo-Sure automatically adjusted for the new shutter speed setting — it was an all-mechanical analog computer!

The camera's focus was fixed, but for close-up subjects a snap-on lens attachment added magnification and slightly changed the angle of the two lenses — like crossing your eyes to thread a needle (Figure D). For indoor or night shots there was a flash unit that synced to the camera and fired flash bulbs.

After you took the pictures, the film was developed like any other roll of slide film. Instead of being cut up and mounted into individual slides, the film would be left uncut as one long strip.

With other 3D cameras, you'd have to carefully measure and cut the left and right images from the filmstrip, then manually trim and mount them into a frame, spacing and aligning the images by hand. One slip of the razor blade or sloppy alignment and you'd ruin your picture. Again, too much trouble for most casual photographers.

No worries. The next element of Gruber's system, the View-Master Film Cutter, made it



E

Press the lever down — kaCHUNK! — and both left and right images were crisply punched out with a single stroke.

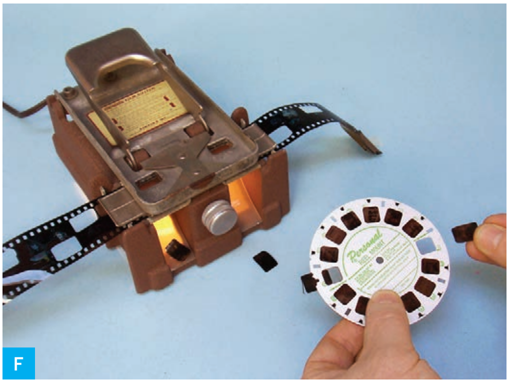
easy to create your own V-M reels. It had twin precision cutting dies and a rock-solid film-strip-advance mechanism. With a twist of the knob, the film's sprocket holes automatically locked into position. Press the lever down — kaCHUNK! — and both left and right images were crisply punched out with a single stroke (Figure F).

Each chip of film was inserted into its matching slot in an empty V-M reel. No tricky alignment needed: the precise slots snugly held the film in perfect registration. There were even blank spaces on the reel to write your own captions for each of your seven images.

Because the V-M reels you made would fit any V-M viewer, you could send reels to friends that they could view with their own (or borrowed) viewers. But for the ultimate in sharing your 3D V-M pictures with a group, there was the Stereo-matic 500 projector, the last part in the V-M system.

The Stereo-matic 500 projector featured twin lenses that automatically aligned the left and right views as you focused. Its polarized filters matched the lenses in the special glasses the audience wore. Your photos were projected in bright, colorful, thrilling 3D for all to see up on the silver screen (a metallic screen surface was required to maintain the polarization).

The entire V-M 3D system worked quite well — and still does! With their rugged construction and clever design, my camera, film punch, and projector still work flawlessly after 50 years. I've taken thousands of 3D images — birthdays and holidays, wedding albums, baby pictures and family events, scenic travel photos, even some "artsy" shots — all with great results (Figure G).



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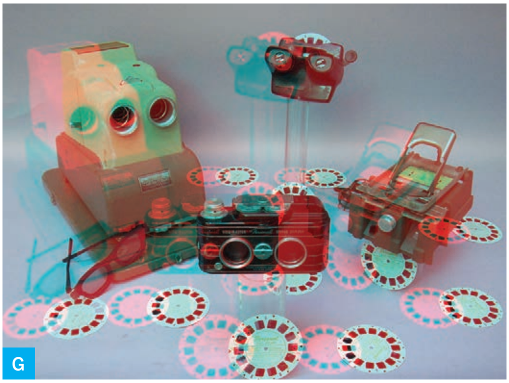

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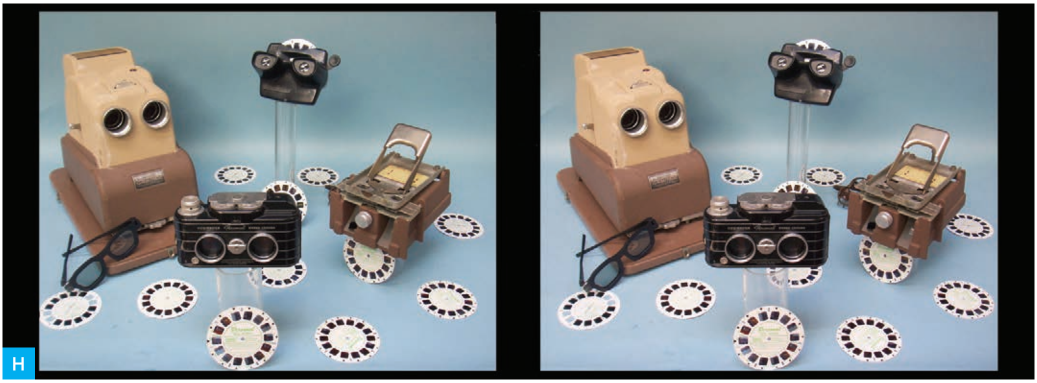

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Fig. E: (Opposite) This 1950s View-Master magazine ad shows Mom, Dad, Buddy, and Sis all diggin' 3D.

Fig. F: Make your own 3D reels with the V-M film punch.

Fig. G: View the anaglyph in Figure G using red/green filter 3D glasses. Remember: right eye = red.

Fig. H: You can see Figure H in 3D by "free viewing." Hold the page at arm's length and cross your eyes. Relax your focus and adjust your gaze so that you see 3 boxes. The center, overlapped image will "pop" into 3D as you focus on the black camera in the middle.

Traveling with the V-M camera is great fun and a real conversation starter among fellow travelers and other photographers. The camera's unique sliding "guillotine" shutter makes a distinctive "pishhhhhht-click" sound with each picture you take and gets plenty of attention, wanted or not. I've gotten curious looks and been asked about my unusual camera on trips abroad. *Qu'est-ce que c'est cette caméra? ¿Qué clase de cámara es ésa?* I just pantomime holding up an imaginary V-M viewer while make the "flicking the lever" gesture, and I get smiles and nods back.

Once an all-ages, all-family product, today the View-Master brand continues only as a preschool toy. Making your own 3D V-M reels is getting harder and harder. Vintage V-M cameras, projectors, and accessories can pretty much only be found on eBay (and at collector prices!), and Kodachrome is now just a colorful song lyric. The empty V-M reels aren't made anymore either: the manufacturer's 60-year-old dies, used to punch out the reels, have gone dull and been abandoned.

But determined DIYers can still have fun making their own V-M 3D reels using modern digital cameras. Turn to page 155 for a new Toy Inventor's Notebook project, the "'Level Best' 3D Camera Bar." You can use it to take stereo digital photos, and then use Photoshop to create red/green anaglyph 3D images, or use a kit to create your own View-Master reels.

With a tug, a swirl, and a "clack," you too can make friends and family go "Wow!" with your own View-Master 3D photos.

Bob Knetzger is an inventor/designer with 30 years' experience making all kinds of toys and other fun stuff.

TOYS FROM TRASH

Arvind Gupta's playful educational mission.

BY ROHIT SRIVASTWA

Arvind Gupta (arvindguptatoys.com) is the creator and driving force behind the popular "Toys from Trash" video series on YouTube, which teaches engineering principles to kids by showing how to make simple toys from common materials. I recently spoke with him in his office at India's University of Pune, and it was difficult to transcribe the interview afterward. Each time I tried, I'd get distracted by making another one of his toys.

Rohit Srivatswa: How did you get started making toys for kids?

Arvind Gupta: I studied engineering at IIT Kanpur in the 1970s, then got a job in the automobile industry making trucks. This was when India was newly free from the colonial era and ready to rise and shine. At the time, there was a national effort to revitalize science education in villages. I joined that program and spent a few months in a village, teaching (and learning from) students — not using books, but by making toys out of the common wares available in a village market.

I soon realized I was not made to build trucks, and this was a turning point for me: from an electrical engineer from one of the most prestigious technical institutes in India, to a man who makes toys out of trash.

RS: What are some of your favorite success stories with this teaching method?

AG: My personal satisfaction comes from seeing the happiness and gleam in the eyes of kids around me who learn new things from my toys. Schools try to cram similar material into students, but when kids do it for themselves — learn basic physical principles that way — their eyes glitter, and that's my happiness.

One favorite story concerns an asteroid called 21575 Padmanabhan. Several years ago I met a girl named Hamsa Padmanabhan. After we met, she wrote a 15-page research paper inspired by my Magnetic Levitating Pencil toy. The paper won multiple awards at the 2006 Intel International Science and Engineering Fair, and afterward, astronomers at MIT named the asteroid in her honor. She

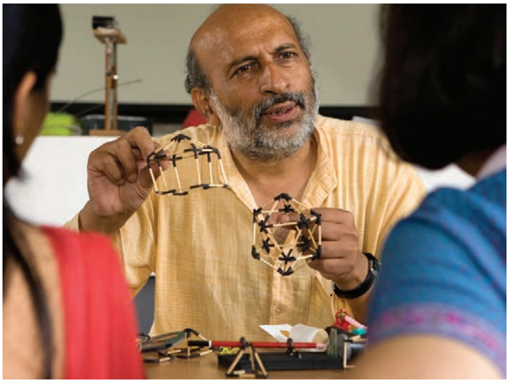
SMART, CHEAP, AND FUN

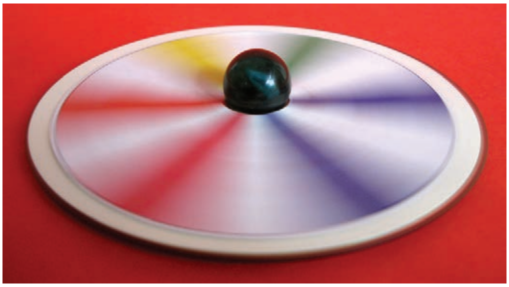
Arvind Gupta demonstrates Matchstick Meccano geometric solids made of matches and bike valve tubes.

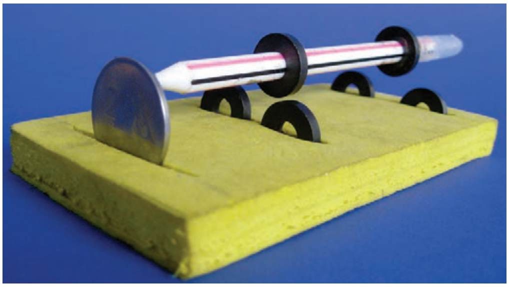
Newton's Color Disc made from a CD and a marble.

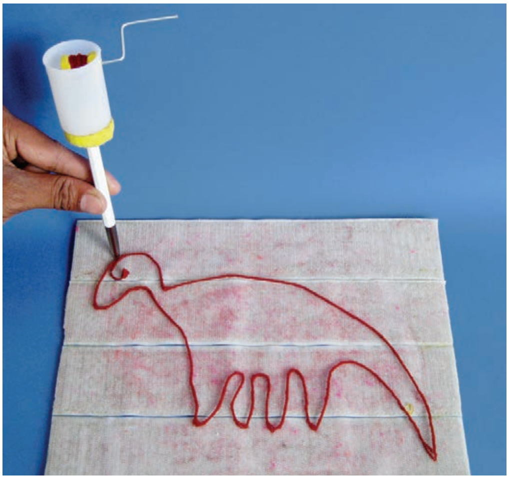
The Magnetic Levitating Pencil toy that inspired Hamsa Padmanabhan's award-winning research paper.

The Touching Slate draws with yarn on velcro.









was just 16 at the time, and she's currently doing her postgrad in physics here at Pune University. She is a star now — literally!

RS: How can people support your work?
AG: I have just one request: translate my videos into as many languages as you can, and gift it to kids across the globe. All I want is the happiness in their minds from knowing that they can create things. My work is available in text format as well as video, and volunteers have translated it into many Indian languages already. Now I just hope that more people will make it accessible in other locations that lack heavy monetary resources for helping kids learn and grow. My toys are low-cost so that anyone can afford making them without worrying about money. So please go ahead and spread the good work; the kids will bless you for doing that.

There's another request I have for teachers: let students make such toys themselves and do some practical learning, rather than just cramming them with text on paper.

RS: Tell us about one toy that touches your heart.
AG: The Touching Slate was devised by a friend-couple for their blind child, Nikunj. It's a pen that "writes" with a spool of wool yarn on a panel covered with the hook side of velcro. Blind kids can use the slate to make shapes and recognize them by feel, but it's fun for sighted children as well. Together, these friends of mine and I have made many such slates and gifted them to blind kids.

See makezine.com/28/gupta for instructional links to all the toys mentioned in this article, plus additional photos and video.

Ashok Rupner

Rohit Srivastwa (rohit11.com) is a leading network security evangelist based in Pune, India. He founded ClubHack and its free e-magazine CHMag (chmag.in).

CLOTHES-LINE RACES

This high-flying contest tests robotic prowess, creativity, and sense of humor.

BY JOHN BAICHTAL

Last November, a group of makers took their robots to Minneapolis' Hack Factory hackerspace. These robots didn't roll around on the floor following a line, fighting, or picking things up. Instead, they did one thing: move along an ⅛", 100' length of woven steel aircraft cable and, upon reaching the end, return to the starting point — as fast as possible. It was a Clothesline Race, a contest invented by the hackerspace's founding president, Mike Hord.

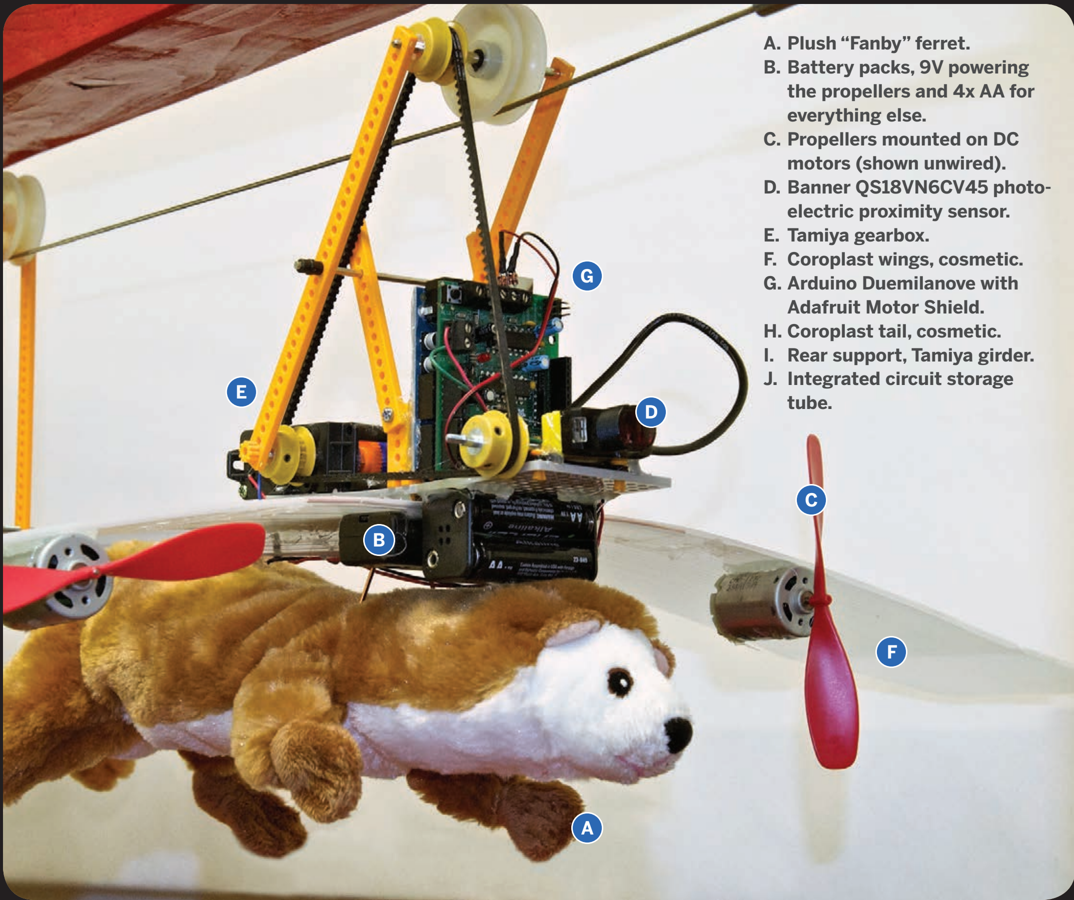
Hord's fascination with this sort of race goes back more than 20 years. As a child, he was obsessed with a Cub Scout event called Space Derby, in which toy spaceships run along cords, powered by rubber bands and propellers. Space Derby isn't nearly as popular as the Scouts' Pinewood Derby, in which Scouts build and race wooden cars, a fact that Hord attributes to the Space Derby's greater complexity. "To keep the playing field level," he says, "you need to provide a more complete kit and allow less leeway, because the task is harder and there are so many more ways to solve it."

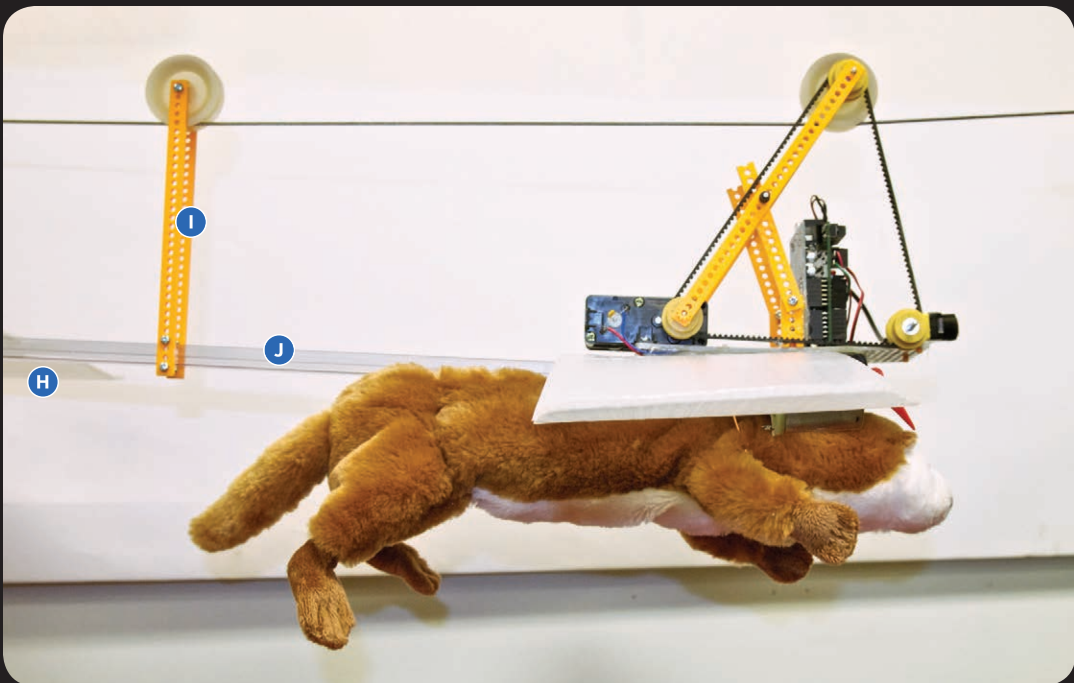
But Hord came to realize that what was a liability for a kids' event made for a fascinating challenge as an adult. When he helped found the Hack Factory, he saw his opportunity to organize his own Space Derby — upgraded for more sophisticated, adult makers.

In a Clothesline Race, the track is a length of rope or cable, stretched taut and level, with a metal plate at either end. Unlike the Cub Scouts' Space Derby, there is no kit. Your racer can use virtually any technology, so long as it's safe. Depending on the specific race's rules, racers can be propelled by anything from Lego Mindstorms servos to model airplane props to Estes rocket engines.

Some of Hord's ideas have included a can-and-pipe Stirling engine (*see MAKE Volume 07, page 90*) and a wi-fi-enabled crawler. "I've also had ideas for a brachiating racer built into a stuffed monkey, a gyro-stabilized racer

John Scherer





A. Plush "Fanby" ferret.
B. Battery packs, 9V powering the propellers and 4x AA for everything else.
C. Propellers mounted on DC motors (shown unwired).
D. Banner QS18VN6CV45 photoelectric proximity sensor.
E. Tamiya gearbox.
F. Coroplast wings, cosmetic.
G. Arduino Duemilanove with Adafruit Motor Shield.
H. Coroplast tail, cosmetic.
I. Rear support, Tamiya girder.
J. Integrated circuit storage tube.

that balances on the wire, and a propeller that somehow uses the wire as its hub," Hord says. "Or at the other end of the spectrum, designs that are as simple as possible: a bristlebot-like microracer, a couple of balloons with a straw, and something based on a rat trap."

BUILDING A RACER

Hord's latest racer looks like a ferret suspended underneath an airplane, an ode to a couple of early xkcd comics. It consists of an Arduino, an Adafruit Motor Shield, a Tamiya gearbox, a few motors, and a Banner proximity sensor. Hord salvaged most of the parts. "The propellers came from hardware store balsa gliders and their motors from some of my daughter's outgrown baby seats," he says. The spine is an IC storage tube, and the wings are pieces of Coroplast boxes salvaged from Hord's office dumpster, where he also found the sensor.

Each clothesline racer consists of three basic components: a motivator, a direction-reversing mechanism, and something that couples the first two components to the wire. The simplest design is a motorized wheel with a switch that reverses current to the motor when the racer hits the end plate. But if the racer is traveling too fast, it'll smash to pieces when it hits. Some participants program their racers to slow briefly before they reach the plate. Others add springs or bumpers to reduce the impact damage.

Clothesline races are so experimental that they often turn into impromptu improvement-and-repair sessions, with participants hunching over soldering irons and glue guns between heats, trying desperately to fix bugs and eke out more speed. If you participate, make sure to take your tools to the race.

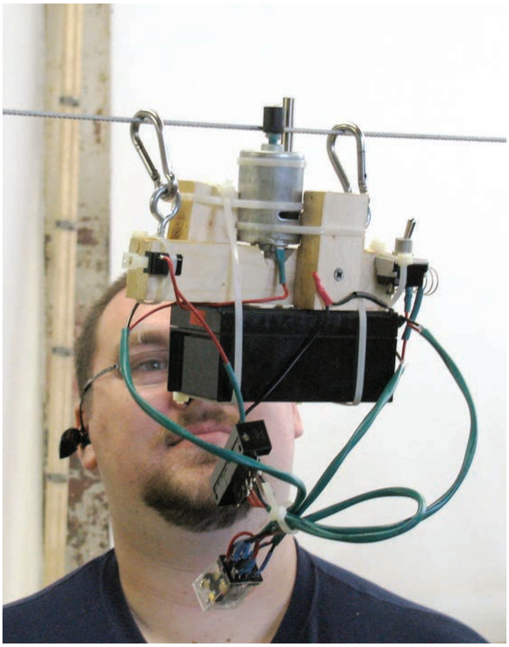
RUNNING A CLOTHESLINE RACE

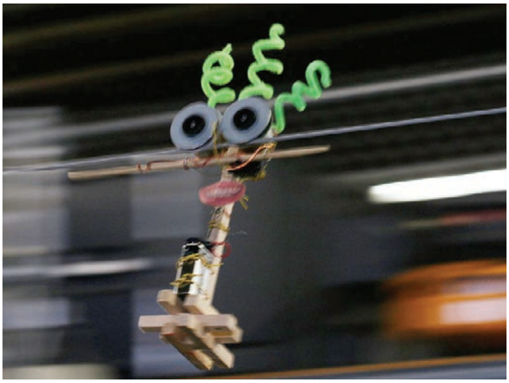
To hold a race, all you need is a long, taut wire (racers can get trapped if it sags too much). With a lot of beginners participating, skip the requirement that racers travel back to the starting point. Conversely, with advanced makers, you can add complexity: hang the wire at a slant, or require the robots to drop things or pick them up.

To save time, make the wire available for participants to test out their racers in advance. Even a relatively modest race with a half-dozen contestants can take several hours. Each heat takes only a minute, but a racer won't necessarily be ready to roll when its turn comes up. Race-day tinkering and spur-of-the-moment creativity are part of the fun.

Safety is paramount. You don't want anything that could explode, start a fire, or spin off the wire into the spectators. "On our last race day, we had one racer that covered the course in a bit more than five seconds, pushing 25mph," Hord recalls. "That racer had two model aircraft propellers on it, and when it hit the plate it exploded into quite a few big chunks, two of which were essentially spinning plastic knives. Nobody was injured, but we learned a lesson in caution regarding having people too near the end of the course."

Peter Tirsek





ON THE LINE (Opposite) Scott Hill built his clothesline racer using a Lego Mindstorms microcontroller brick, servos, and sensors.

SPEED RACER (Clockwise) Hack Factory member Brandon Paplow inspects his racer. Adding a little whimsy to your racer can only help you win points.

RULES AND PRIZES

Under Hack Factory rules, each racer:

» *Must be self-contained in terms of power and control.* The exception is that the racer may be manually activated at the beginning of the run.

» *Must weigh less than 3lbs, fully fueled.* This is based on the strength of the line. A very strong cable solidly anchored at either end might not need a weight limitation.

» *Must not exceed 12"×12"×12".* This prevents cheats like telescoping extenders that would enable the racer to reach the end plate faster than it ought.

» *Must complete the circuit.* Racers begin the race in contact with the initial stop, make contact with the far stop, then return to contact the first stop.

» *Must be able to be placed quickly and easily on the wire.*

» *May not damage or adulterate the wire or stops.* No residue, soot, char, rubber, goop, or anything else left behind, and no cutting or abrading.

» *Must finish the race with all parts (except fuel) intact and still within the cubic volume.*

» *Must be safe for other racers and spectators alike.* No racer may use liquid-fueled rockets; jet engines; high-pressure air, water, or steam mechanisms; or other elements deemed dangerous. Solid rocket motors must be store-bought, not larger than ¼A rating in size, and limited to two per racer.

Each racer gets up to three starts and must complete two runs, its best time being its score. Failure to complete the course after three attempts disqualifies the racer, and judges may rule that a racer is failing to make headway if it does not move for 30 seconds.

Prizes for the event are awarded for Speed, Creative Appearance, Creative Locomotion (method of propulsion), Loudest, Size (smallest and lightest), and Epic Failure. Note that the last of these must be judged an honest, unintentional failure.

John Baichtal is a contributor to MAKE and the GeekDad blog on wired.com.

Bob Poate (right)

POP-POP STEAMBOAT

Build a toy steamer that runs only on heat and the water it's floating in.

BY WILLIAM ABERNATHY

When you picture a steam engine, you likely imagine a giant cast-iron contraption festooned with knobs, valves, gauges, linkages, and wheels. This steam-powered toy boat has no moving parts and needs only a flame and the surrounding water to zip around and make its distinctively happy sound.

My interest in pop-pop boats began when I saw Hayao Miyazaki's stunning children's movie, *Ponyo*. In it, Ponyo and her friend Sosuke sail a scaled-up version of Sosuke's pop-pop boat around a flooded city. The boat requires only a candle and some water to run.

Once commonplace, these toys have given way to battery-powered plastic. But the pop-pop boat's underlying principle is compellingly simple and provides the home tinker with endless room for futzing and improvement.

PEDIGREE AND PRINCIPLES

First patented in 1891, pop-pop boats use a candle or other flame to heat water in a small boiler connected to one or more pipes. The pipes run down and back into the water behind the boat; when the water in the boiler turns to steam, it pushes jets of water backward out of the pipes, propelling the boat forward.

The moving water's momentum makes the steam "piston" overshoot its equilibrium, so the steam quickly cools, contracts, and condenses back into water. This draws cool water back up through the pipes and into the boiler, where the cycle starts again. Because the water sucking back into the tube is incoherent, coming in from all directions, rather than in a directed jet, this intake cycle doesn't pull the boat backward. (By analogy, you can easily use a straw to blow a small ball of wadded-up paper across a table, but you can't suck it up the straw unless you're right on top of it.)

You can think of a pop-pop boat as a reciprocating, steam-driven water hammer, an engine with pistons made of water, or an external combustion pulsejet (*see MAKE Volume 05, page 102, and makeprojects.com/project/j/57*).

A later design (patented in 1916) added a "sound producer" to the boiler, a slightly convex sheet-metal diaphragm that flexes with the expanding and contracting steam. The resulting rattle makes the motor sound more mechanically complex than it actually is, and

Gregory Hayes

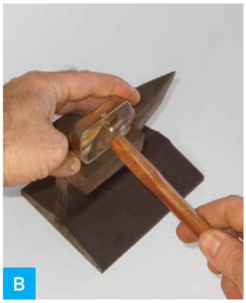
MATERIALS

Altoids Smalls mint tin
Aluminum soda can
Small floating vessel such as a toy boat or a 16oz ham can
Thin-wall copper tube, ⅛" OD, 1' length from hobby or hardware stores. Do not use ⅛" malleable copper coil.
J-B Weld high-temperature epoxy
Solder and flux Lead-free solder is best.
Spirit lamp (alcohol burner) or small candles such as tea lights or birthday candles

TOOLS

Screwdriver, flathead, small
Hammer, small If your hammer's too big to work inside the Altoids tin, a brass drift is handy to tap on. MacGyver could make do with light whacks to a ⅜" bolt.
Anvil or other flat surface to pound on
Marking gauge or odd-leg calipers aka "jenny" or "hermaphrodite" calipers
Machinist's scribe
Tinsnips
Pliers Lineman's pliers are best for this project.
File
Prick punch or center punch
Drill or drill press
Step bit
Small tubing cutter or jeweler's saw Ordinary hacksaw blades are too coarse for the thin-wall tubing. I used a jeweler's saw. Micro-Mark's mini tubing cutter also looks right for the job.
Propane torch
Sandpaper, 80 grit
Plumber's putty or modeling clay


A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F

gives the pop-pop boat its name.

Traditionally these boilers are built with a thin brass diaphragm crimped and soldered into place. Thin-enough brass stock can be hard to find, so I've come up with a design that uses castoff packaging instead: an Altoid Smalls tin boiler with an aluminum can diaphragm. Since aluminum can't easily be soldered, I've substituted J-B Weld epoxy, which is up to the task: its maximum operating temperature of 500°F exceeds the melting point of most soft solders, and its tensile strength is comparable.

Ponyo notwithstanding, this type of engine does not scale up to life-sized boats (nor, for that matter, are there sea wizards or magic talking fish). Nonetheless, there's an undeniable pleasure in a home-built toy that scoots around on its own and has no use for batteries — except, perhaps, as ballast.

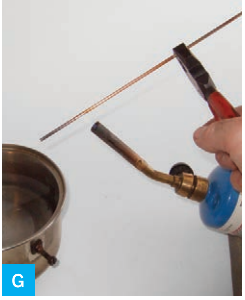
START

1. DISMANTLE THE MINT TIN.

Using a small, flathead screwdriver, gently pry the hinges of the Altoids Smalls tin apart and lift away the lid (Figure A). Save it.

Carefully flatten the stamped hinges of the bottom half by tapping them with a small hammer (Figure B). If your hammer is too big to fit, you can squeeze in a small brass drift or ⅜" bolt, and then tap this with your hammer to flatten the hinges.

William Abernathy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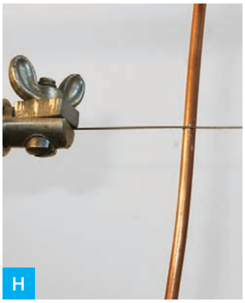
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2. PREPARE THE BOILER HALVES.

Circumscribe a line 3⁄32" from the top edge of the tin's bottom half. Scribe a second line 3⁄16" below this, 9⁄32" from the top edge of the tin (Figure C).

Cut along the top line with tinsnips, removing the rolled bead from the tin (Figure D). Notch the corners of the tin, cutting 90° V's to the remaining scribed line. As tidily as you can, fold the tabs along the remaining line so that they all point inward toward the center of the tin (Figure E). Lineman's pliers work well for this.

File down the folded corners of the bottom half of the tin until you can press the lid all the way back on.

Take the lid off, flip the bottom over, and scribe a line 9⁄32" from one end, parallel to the barcode. Scribe 2 more lines perpendicular to the barcode, 3⁄8" in from the hinge and clasp edges of the tin. Make punch marks at the 2 intersections with a prick punch, and drill 1⁄8" holes at each (Figure F). Sand away the varnish and paint from the area around these 2 holes.

WARNING: **Copper conducts heat quite quickly, so use pliers or some other device (not your hand) to hold the tube while you heat it.**

3. ATTACH THE JET TUBES.

Anneal (soften) the copper tube so that you can bend it without kinking it. Copper anneals differently than steel or glass: heat it with a propane torch until you see its surface color change, and then quench it in cold water (Figure G).

Use a small tubing cutter or jeweler's saw to cut two 6" sections of tubing (Figure H). (Don't use wire cutters, which crush before they cut.) Make sure all ends remain open.

Gently bend the tubes into identical J shapes starting 2½" from one end and curving slightly past 90° (Figure I). Sand the tips of the curved ends.

Apply flux to the sanded area around the holes in the tin bottom and to the sanded tube ends. Poke the fluxed end of each tube into the tin bottom, just far enough to rest easily in its hole, then solder the tubes in place (Figure J). Try to keep the tubes parallel. It's easy to "sweat" these into position with a propane torch, but if you aren't confident in your torch skills, you can epoxy the tubes in later rather than soldering (before you cement the lid down!). Make sure the tubes are clear of solder before you go on.

4. CUT THE DIAPHRAGM OPENING.

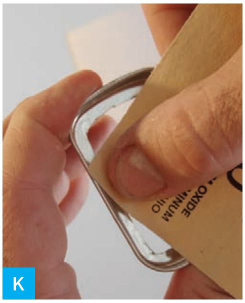
On top of the Altoids lid, scribe lines 3⁄16" in from each edge to describe a "window." Drill a hole in the center large enough to admit the tip of your tinsnips, then cut out the window. Gently hammer the edges flat and sand off any sharp spots. Sand the varnish off the inside of the lid (Figure K, following page).

5. MAKE THE "POP" DIAPHRAGM.

Cut the top and bottom off the aluminum soda can, make a vertical cut, and lay the skin of the can out flat on your bench.

Place the Altoids lid rim-down on this aluminum sheet. Scribe around the lid onto the sheet (Figure L), then cut along the lines with tinsnips to create a leaf of aluminum.

Gradually trim down the edges of the leaf until you can just tuck it into the lid of the tin without it wrinkling. Once you've fitted the leaf, pop it out again, taking care not to crease or tear it. Cut or file away any "needles" or other sharp features on the leaf.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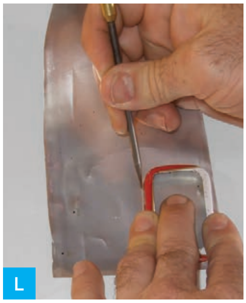
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6. SEAL THE BOILER.

Lay out dollops of J-B Weld epoxy and hardener on a disposable surface.

Sand both sides of the aluminum leaf about $\frac{3}{16}$" in from the edges, all the way around, to take off paint and the oxide layer that clings to the aluminum (Figure M). Quickly, before oxides can re-form, mix the J-B Weld together with a stick and apply it to the inside of the lid. Lay the aluminum sheet inside the lid.

Smear the J-B Weld over the flat flanges you folded into the tin bottom, paying special attention to the gaps in the corners (Figure N). Press the bottom and the lid together, sandwiching the aluminum between them. Apply J-B Weld all the way around the gap between the lid and bottom, and smear some into the hinge holes in the side of the lid.

If the aluminum leaf looks sunken or gapped around the edges, blow into the copper tubes to push it up — if you have to do this, you'll push out some of the wet J-B Weld, so look for fresh air gaps. Using a clean, disposable rag, wipe any excess J-B Weld off the surface of the aluminum (Figure O). Allow the J-B Weld to cure overnight.

7. PRESSURE-TEST THE BOILER.

Immerse the boiler (Figure P), put both tubes into your mouth, and blow. If you see bubbles, you have a leak. Patch it with more J-B Weld.

When the J-B Weld is dry, test the diaphragm again: put both tubes in your mouth and suck and blow — the diaphragm should pop down and up. If it's too tight, loosen it a little by pressing firmly on its center with your thumb.

8. FIT THE MOTOR TO YOUR BOAT.

For a boat, you can use anything small and light that floats and doesn't catch fire. For simplicity I used a 16oz ham can (Figure Q), but you can make as awesome a boat as you like. You can also fit a rudder to the stern.

Measure the outside distance between the 2 tubes where they bend, subtract $\frac{1}{8}$", and drill 2 holes to this measurement in the bottom of the boat, equidistant from the center. Your punch will help get these holes started. Depending on the shape of your boat, fitting


Q

the motor in may take a little re-bending of the tubes. Be careful of hard spots in the tubes and be ready to re-anneal them.

You can solder the tubes into your boat to seal them, but it's easier to just use plumber's putty or modeling clay, which you can remove to make repairs or adjustments.

USE IT

To make your boat go, *you must first prime the engine with water*.

Turn the boat over and pour water into one of the tubes until it dribbles out the other tube. You don't need to fill the boiler completely: just make sure you can hear water sloshing around inside. Hold a finger over the ends of the tubes and lower the boat into the water without letting any water pour out.

Light candles or a spirit (alcohol) lamp, and place them under the boiler. In about a minute, you'll hear the water boiling into steam.

First, a few bubbles will come out, then the boat will start puttering along in the water, and as the reaction becomes more vigorous, the diaphragm will start its obnoxious song. If the motor stops, blow out the fire, or the heat may damage the seal of the boiler.

WARNING: If you blow down one of the boiler tubes, very hot water can come out the other tube, shooting you in the face with scalding water. Don't do this — it will hurt.

William Abernathy (yourwritereditor.com) is a compulsive writer, editor, and tinker. He lives in Berkeley, Calif., and flatly denies tracking metal chips onto your carpet.

RUNNING ON SPIRITS

Using candles for any length of time will coat the bottom of your boiler with soot and leave a greasy black ring in your bathtub or sink. To avoid this, use a spirit lamp. You can make a simple one by drilling a hole in the metal lid of a very small glass or metal container, threading through a lantern wick, then filling the container with denatured alcohol.

I've also made spirit lamps out of copper pipe caps and copper tubing. Cut a 1¼" pipe cap short enough to fit under the boiler with room for the flame, then sweat-solder it onto a sheet metal bottom. Drill holes in the cap and solder in 2 lengths of ¼" tubing: a very short one on top (the wick holder) and a longer one in the side (the filling tube and handle), bent upward.

With candles, this engine needs more than a single small flame to get moving. Use 2 or 3 birthday candles or a tea light with more than one wick.

Gregory Hayes (lamp)

See how MAKE Labs engineering intern Daniel Spangler made a copper pipe alcohol lamp, at makeprojects.com/v/28.

PERMISSION TO PLAY

MAGNIFICENT MOUSETRAP, MAGNIFIED

THERE'S SOMETHING INHERENTLY DELIGHTFUL about a familiar object made gigantic. Mark Perez' Life Size Mousetrap taps into this whimsy-by-magnification as it transforms the children's board game Mouse Trap into a Technicolor variety show. It's a 30-foot-high, 16-piece, 50,000-pound, Rube Goldberg-style interactive kinetic sculpture set on a 6,500-square-foot game board, with an entourage of clown engineers and can-can dancer mice. An iconic crowd-pleaser at Maker Faire, the spectacle culminates in dropping a 2-ton bank safe from a crane. lifesizemousetrap.org

—Laura Cochrane

PING! Augmented Pixels

Your hands are the controllers in this retro-style, *Pong*-like video game developed by Niklas Roy. *PING* employs a video camera to capture the movement of your hands, and feeds the information to an ATmega8 microcontroller that evaluates the brightness around the virtual ball and incorporates your hands into the game. Make your own with the code and schematics provided. niklasroy.com/project/101

—Nick Raymond

WHAT'S COOLER THAN an automatic Nerf gun? An automatic Nerf gun controlled by your mind!

Blow Your Mind

BUILT BY CHRIS MEYER, the modified Nerf N-Strike Stampede incorporates an Arduino Uno with BlueSMiRF Bluetooth, controlled by a NeuroSky MindSet EEG reader strapped to the user's head. Meyer says firing the gun feels "like a tickling or a rush of blood to the front of the head." hex-machina.com/hw/mindbullets —*Craig Couden*

LONG-DISTANCE DOODLING

Andrew Little, 22, brings the classic Etch A Sketch toy into the networked age with Connect A Sketch, which links two sketch screens together. A line drawn by one user appears on both screens, thus enabling collaborative plotter art. When one person decides to erase the drawing by shaking, the sister screen vibrates, telling the other user to do the same. designalittle.co.uk/connect-a-sketch —*LC*

FUN FOR ALL AGES

PRINT YOUR OWN, BUT DON'T TELL MILTON BRADLEY.

ROLL OUT THE BARREL

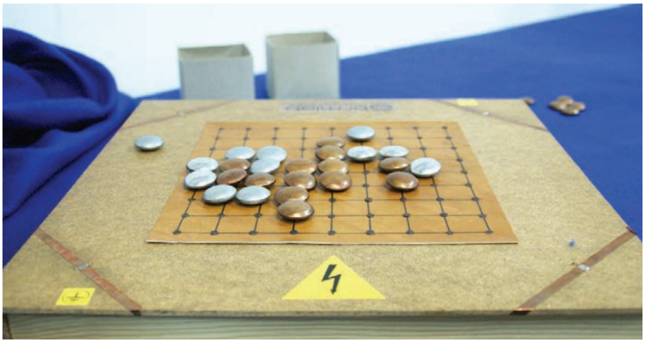
You know those best-selling games that consist of nothing more than multiple copies of one small plastic shape? You may see a resemblance between one such game and Seth Horowitz's "Monkey for Container Full of Primates" design, published on the 3D sharing site Thingiverse. thingiverse.com/thing:3748

—*Paul Spinrad*

HIGH ROLLER

WELCOME TO THE GATEWAY KIT: perfect for newbies and beyond, with through-hole soldering, abundantly clear instructions, and a well-labeled PCB. When you're done with the fun build, tap the die on the table and get a random roll. Life is short, impress yourself. makezine.com/go/dicekit

—*Goli Mohammadi*



Go Twitch

Radka "Chidori" Haneckova, 24, drew a comic celebrating Go, the ancient Chinese board game. In one panel, she depicted a version where players receive electric shocks — so she decided to actually build it. Her "Live Wire Go" board has an Arduino that controls a novelty shocker toy, to send non-lethal voltages unpredictably through the aluminum and copper game pieces. The board was a surprise hit when it debuted at a game convention in Prague, with players coming back for more. brmlab.cz/project/goban

—*John Baichtal*

sheeryjay (Go Twitch)

For tons of playful DIY projects, including Shrink Film Gaming Minis, a Pillow Mace, and rockets galore, head to: **makeprojects.com/area/toys_and_games**

One Drop Yo-Yos

One Drop makes amazing high-precision metal yo-yos, including one called the CODE1 whose specs were community-decided. Now they've developed a new hub design with interchangeable hub parts dubbed "Side Effects" that let you change the weight and look of your yo-yo; one even lets you connect Legos. To boot, all their products are designed and manufactured in Eugene, Ore. onedropyoyos.com

—Eric Chu

TINY DIVER

AT 20 BUCKS, this mini R/C submarine offers hours of fun underwater exploration. Capable of diving 8–10 feet deep, it's powered by two independent motors that control forward, reverse, turning, and diving. Plus, it's intrinsically buoyant, so when the batteries fully discharge, it'll float to the surface for easy retrieval. Plug it in for five minutes, and you're ready to dive! mini-rc-cars.net/minircsubmarine.aspx *—NR*

FOR KIDS INTERESTED IN ROBOTICS, CUBELETS ARE A GREAT JUMPING-OFF POINT.

BOT BLOCKS

This kit consists of modular, single-task, magnetic blocks with functions that include distance and temperature sensing, driving, and audio. Connect the Cubelets and your robot can think, sense, and act. The manufacturer is also working on a Bluetooth Cubelet that will make each Cubelet reprogrammable using a phone or PC. modrobotics.com/cubelets *—LC*

Make:
TOYS AND GAMES

RADPROJECTS

WHISKEYDROME

What do you get when you mix a vintage board track with a shrunken velodrome? Head-spinning mayhem in the form of the Whiskeydrome, handcrafted by the badasses at Whiskeydrunk Cycles in Santa Rosa, Calif. The track has a 26-foot diameter at the top lip tapering to 18 feet at the bottom, and its current bicycle speed record of 17.7mph was clocked by Slow Larry at the 2011 Maker Faire Bay Area. This homage to motor stunt shows from the 1900s will put your neighbor's skate ramp to shame. whiskeydrunkcycles.com

—GM

DIY PLAYGROUNDS

THE FOLKS AT THE NONPROFIT KABOOM are passionate about the importance of play. Their mission? To ensure that every child in America has a place to play within walking distance. So far they've helped local folks build 2,000 playgrounds, using their DIY instructions in grant writing, playground construction, landscaping and seating, and more. Sounds like a lot of fun!

kaboom.org *—GM*

JediBot

If you find your Jedi skills are getting a little soft, students from Stanford University have just the solution: JediBot. Created during a three-and-a-half-week Experimental Robotics course, the dexterous robot uses a Microsoft Kinect sensor and some AI to defend itself — and attack you — with its saber. I believe this is how the Clone Wars started.
makezine.com/go/jedibot

—Jerry James Stone

Jon Lohne (Whiskeydrome)

Billboard Swing Set

Fly above the playground with this billboard-sized swing set. Built by French artist/architect Didier Faustino in Shenzhen, China, *Double Happiness* attempts to re-appropriate commercial billboard space for personal use.

This one's built from scratch, but intrepid makers could convert their own. Jump off at your own risk! makezine.com/go/swingset

—CC

LEAVE YOUR TIGHTS AT HOME AND STILL LOOK GOOD FIGHTING CRIME WITH YOUR OWN FLYING R/C SUPERHERO.

HIVEMIND FOR KIDS

Researchers at Indiana University Bloomington have developed a fun game (or "participatory simulation") called BeeSim to demonstrate systems thinking and collaborative learning to children ages 5–7. Wearing Arduino-powered bee puppets laced with conductive fabric and XBee radios, players respond to LEDs mimicking basic bee stimuli in a race to harvest digital nectar from electronic flowers and fill their team's computerized hive. And if that doesn't sound like my last desk job, I'll bee darned. makezine.com/go/beesim

—Gregory Hayes

UP, UP, AND AWAY!

SOLD AS A KIT OR A PLAN from Greg Tanous of Portland, Ore., the RcSuperhero's simple but elegant cut-foam shapes give the radio-controlled flier a heroic human figure that will delight fun-lovers and strike fear into the hearts of evildoers. rcsuperhero.com

—GH

1+2+3

Mini Foosball Game

By Cy Tymony

You can make it!

FOOSBALL (TABLE FOOTBALL) GAMES are a lot of fun, but they're usually found at bars or clubs. That shouldn't stop a true maker from enjoying foosball at home.

With just a few straws, paper clips, and a common 3-bag microwave popcorn box, you can quickly put together your own Sneaky Mini Foosball Game.

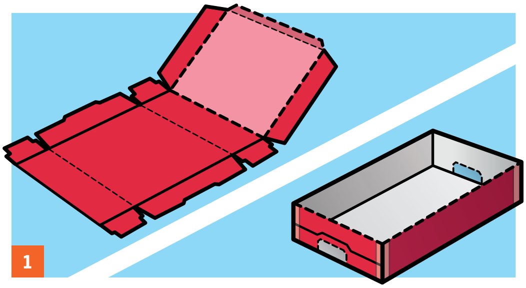
YOU WILL NEED

Microwave popcorn box, 3-bag size
Straws (4)
Jumbo paper clips (8)
Gumball or jawbreaker candy
Scissors
Tape

1. Prepare the cardboard.

Open and flatten the popcorn box. Cut off the front of the box, but don't trash it — it'll be used to make sneaky game paddles.

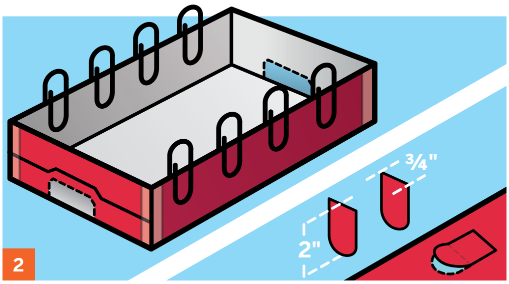
Fold the cardboard back into a box shape and tape the ends together. Be sure to cut holes at each end for the game ball to exit.



2. Prepare paddle guides and paddles.

Affix 8 paper clips onto the long sides of the box, 4 per side, evenly spaced. These will act as paddle guides.

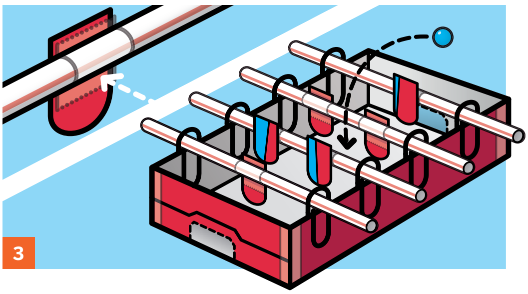
Using the cardboard front you saved earlier, cut 6 paddles approximately ¾" wide by 2" long, oval at one end and square at the other.



3. Attach paddles and straws.

For the "players," tape 2 paddles near the center of 2 straws as shown. For the "goalies," tape 1 paddle each at the center of 2 straws. Slip the straws into the paper clip holders with the goalies at each end, and you're done. (You can also slide the straws through the guides first and then attach the paddles — either way works.)

Place the candy ball on the game board area and start the action.



Going Further

To make a Sneaky *Micro* Foosball Game, go to makezine.com/28/123_foosball.

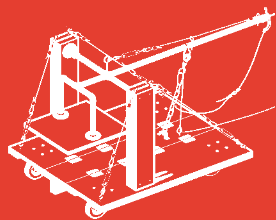
Damien Scogin

Cy Tymony is the author of the *Sneaky Uses for Everyday Things* book series. He lives in Los Angeles. sneakyuses.com

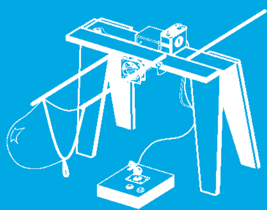
Make: Projects

Build a medieval-tech gravity catapult (trebuchet) that hurls hefty payloads and folds small for storage. Make a magical machine that blows enormous soap bubbles, either on its own or via remote. Finally, modify a teddy bear to speak, make sounds, and play songs, depending on which objects it's near.

84
Gravity Catapult

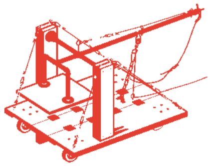


94
Gigantic Bubble Generator



106
RFID Teddy Bear

Roy Ritchie (catapult), Cody Pickens (bubble), Kathryn Roach (teddy)



GRAVITY CATAPULT

Get medieval with this portable, stowable, gravity-powered trebuchet.

By William Gurstelle

I have long been enamored of catapults. Invented around 400 B.C., they were used until nearly A.D. 1300. So for 1,700 years, catapults were arguably the largest, most expensive, and most powerful machines on the planet.

Today, people build catapults for fun: Scout troops, historical reenactors, fathers and daughters, beer-stoked college students. Having built more than a few, I've found it's not nearly as easy as it might appear.

First, for any projectile larger than a golf ball, catapults have to be big, and building big things can be a challenge in terms of cost and tools.

Second, there are incredible stresses at work within the moving parts of a catapult. Unless good designs and materials are used, wooden support beams break, rods bend, and joints collapse in ways unexpected and sometimes even dangerous.

Third, they are big. Did I already say that? Well, it bears repeating because once you build the thing, you need space to use and store it. I've learned that finding a place to store a catapult is a huge pain — very few people are willing to park their cars in the driveway to free up garage space for their catapults, no matter how much they love to hurl.

This gravity-powered catapult is fairly simple to build using a minimum number of tools. Built with modern materials instead of medieval timbers, it's small and light enough for one person to push around. Best of all, it rolls around on wheels and folds flat (sort of) so it can be stored in a fraction of the space needed for traditional catapults.

While the Folding Catapult is customizable, don't get carried away — 120lbs is about the maximum counterweight that can be used.

William Gurstelle is a contributing editor of MAKE. His new book, *The Practical Pyromaniac*, is available in the Maker Shed (makershed.com) and at other fine booksellers.

SET UP: p.87 | MAKE IT: p.88 | USE IT: p.93

Roy Ritchie


Maker Faire

HEAVY HURLING

A *catapult* is any weapon that hurls large projectiles without the use of explosives. The *trebuchet* is a gravity-powered catapult, with a falling counterweight that rotates the throwing arm. Other catapults store and release force using bows, twisted skeins, or springs.

A **Rotating arm** works as a lever, with a long throwing arm at one end and a counterpoise at the other.

B Heavy **counterweight** sits high on the counterpoise deck, storing gravitational potential energy.

C **Chain** holds the throwing arm down close to the deck until launch.

D Catapult operator pulls the **trigger cord** to fire the weapon.

E **Panic snap** attached to the trigger cord disconnects the chain.

F Falling **counterpoise** has its own small pivot. This design uses less space and releases more energy than a fixed counterpoise.

G **Sacrificial sling** hangs on the throwing arm hook and holds the projectile before and during flight. It's easier than a permanent sling, which requires a lot of fiddling to release at the correct time.

H Main **pivot** holds the rotating arm.

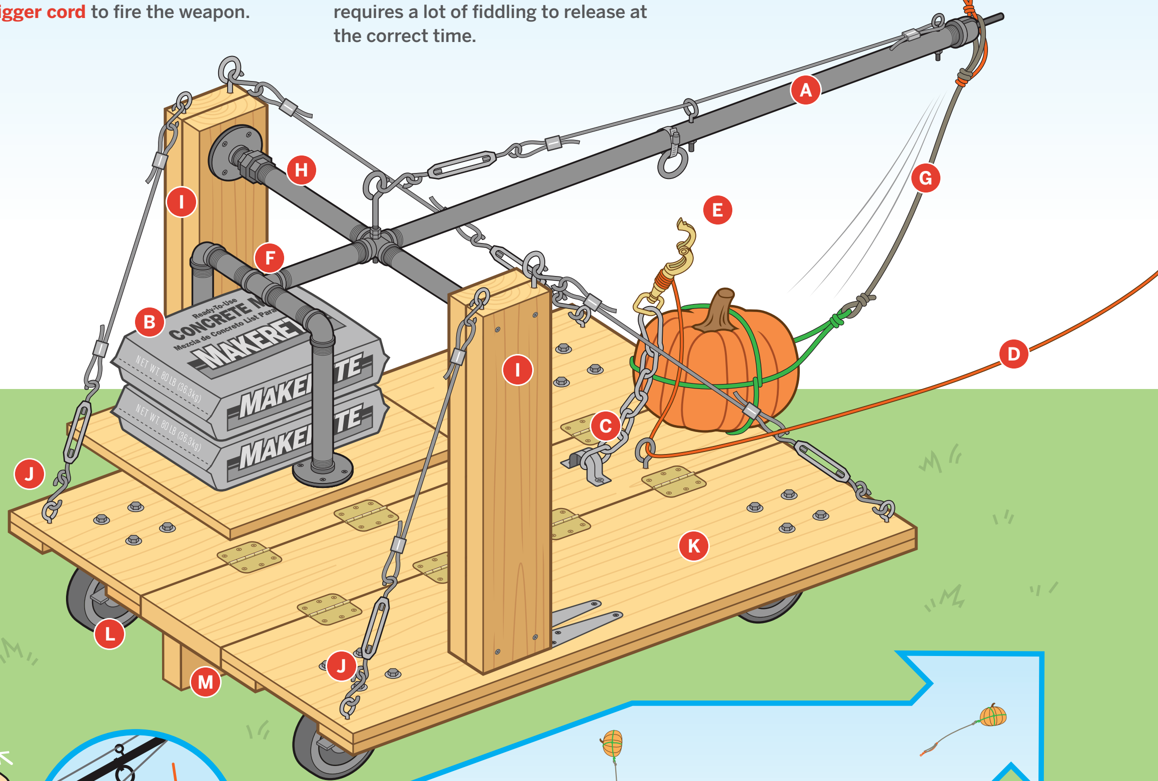
I Pivot runs between two **uprights**, hinged so they swing down for storage.

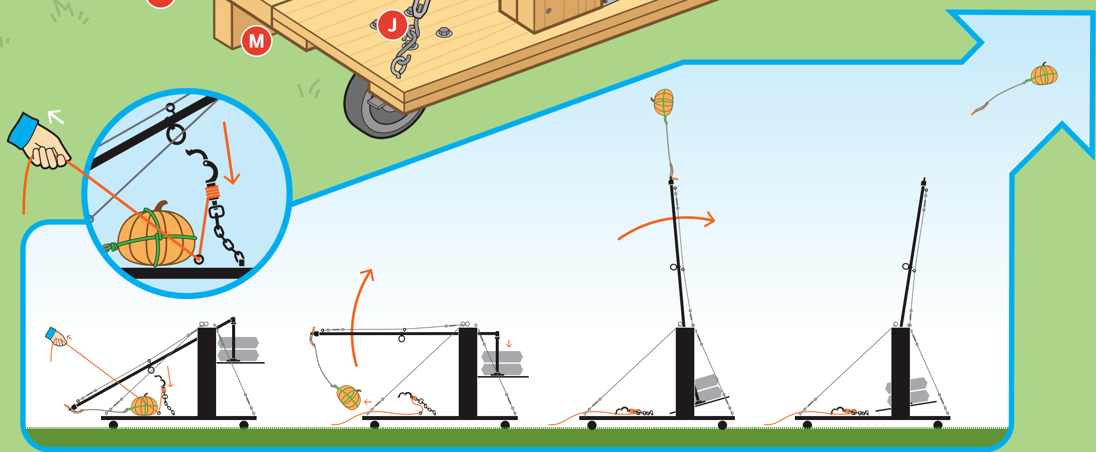
J **Guy wires** stabilize the uprights, connecting them tightly to the deck.

K Hinged **deck** folds for storage.

L **Casters** raise the deck, enabling a longer throwing arm, and letting you roll the catapult.

M **Prop board** unfolds under the deck to prevent rolling during setup or launch.





Timmy Kucynda

SET UP.

A

B

C

D

E

F

MATERIALS

A. Panic snap, equestrian style Find them at tack and saddle shops, feed stores, rural hardware stores, or online.

B. Ferrules or wire rope clamps (10) to fit ⅛" wire rope

C. Turnbuckles, ¼"×5", one end open (5)

D. Welded ring, 1½"

E. Steel pipe fittings, 1", threaded: flanges (4); 1½" close nipples (2); 8" nipples (3); 10" nipples (2); 4" nipples (2); 90° elbows (2); cap (1); unions (2); tee (1); cross (1) A pipe union is shown here.

F. Casters, 4" (4)

- » **Plywood, ¾", 4'×8' sheet**
- » **Lumber, 2×6, 10' length**
- » **Deck screws: 2½" (1 box), 1¼" (1 box)**
- » **Door hinges, steel, 3½" (10)** with mounting screws
- » **Strap hinges, 1½" (4)** with mounting screws
- » **Screw eyes, #4 (9)**
- » **Eye bolts, with nuts and lock washers: 5⁄16"×6" (1); ¼"×4" (2)**
- » **S-hooks, medium (10)**
- » **Hose clamp, 2"**
- » **L-hook, 3"**
- » **Cord, nylon or cotton, ⅛", 25'**
- » **Wire rope, ⅛", 16'**
- » **Steel pipe, 1", threaded, 72" length**
- » **Bolt, ¼"×2", with nut and lock washer**
- » **Duct tape**
- » **Wood screws: ¾" flathead; #10 round head**
- » **Pipe strap, 1", 2-hole** for the trigger support bracket
- » **Chain or rope, 1' or less** for the trigger. We used a brass door-security chain (and used the bracket it came with instead of the pipe strap).
- » **Bolts, 5⁄16"×1½" (16) with nuts (16) and washers (32)** for the casters
- » **Heavy counterweight** The counterpoise will carry up to 120lbs; two 60lb sacks of cement mix work great.
- » **Bungee cords, 18" (optional, 2)**
- » **PVC pipe, 4" diameter, 4' length (optional)** for a projectile trough
- » **Lumber, 2×4, 3' length, with ½"×3" bolt and nut (optional)** for a deck cross-brace

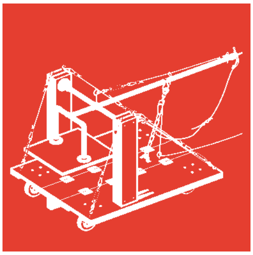
G

TOOLS

G. Pipe wrench

- » **Saw** to cut plywood, such as table saw, panel saw, or handheld circular saw
- » **Tape measure**
- » **Grease**
- » **Electric drill with drill bits and screwdriver bits** A drill press is good for drilling straight through steel pipe and fittings, but a handheld will do.
- » **Hammer**
- » **Socket set**
- » **High-speed rotary tool with cutoff wheel** such as a Dremel, for cutting wire rope
- » **Locking pliers**

MAKE IT.



BUILD YOUR CATAPULT

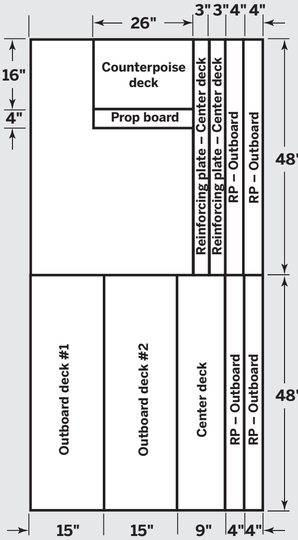
Time: A Weekend
Complexity: Easy to Moderate

1. BUILD THE FOLDING DECK

1a. Using a table saw, or better yet a panel saw, cut out the plywood parts from a 4'×8' sheet of ¾"-thick plywood, referring to the Cutting Diagram at right.

1b. Use the 1¼" deck screws to fasten the reinforcing plates to the deck, following the Folding Deck Layout Diagram below.

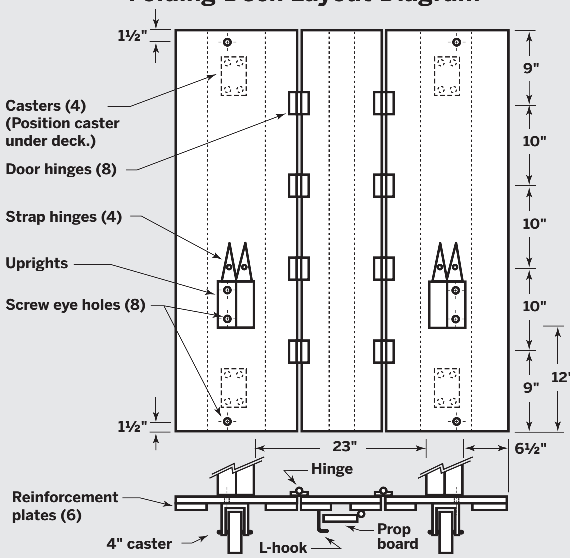
1c. Using an electric drill, mount the door hinges to the deck with their mounting screws (or ¾" flathead wood screws).



Cutting Diagram

1a

NOTE: If you don't have a table saw, don't despair — most lumberyards will cut the pieces for you at little cost when you buy the wood. You could also use a handheld circular saw.



Folding Deck Layout Diagram

1b

Gerry Arrington

2. BUILD AND RIG THE UPRIGHTS

2a. Cut 4 pieces of 2×6 lumber 28" long and fasten pairs together using 2½" deck screws to make the uprights.

2b. Place the uprights on the outboard deck pieces as shown in the Folding Deck Layout Diagram and attach them to the deck with the 4 strap hinges.

2c. Attach 1" pipe flanges to the uprights as shown using 1¼" deck screws.

2d. Now make the guy wires. For this step, you'll need to become familiar with using wire rope. But hey, this is a valuable skill that'll come in handy on many different projects over a maker's career.

Assemble 4 wire slings (clamped segments of wire rope) using the measurements given in the Wire Sling Diagram at right. You can either swage the ends with 8 ferrule fittings, or install 8 wire rope clamps to do the same job.

Install the #4 screw eyes on the ends of the uprights as shown in the Wire Sling Diagram, and on the outboard deck pieces as shown in the Folding Deck Layout Diagram.

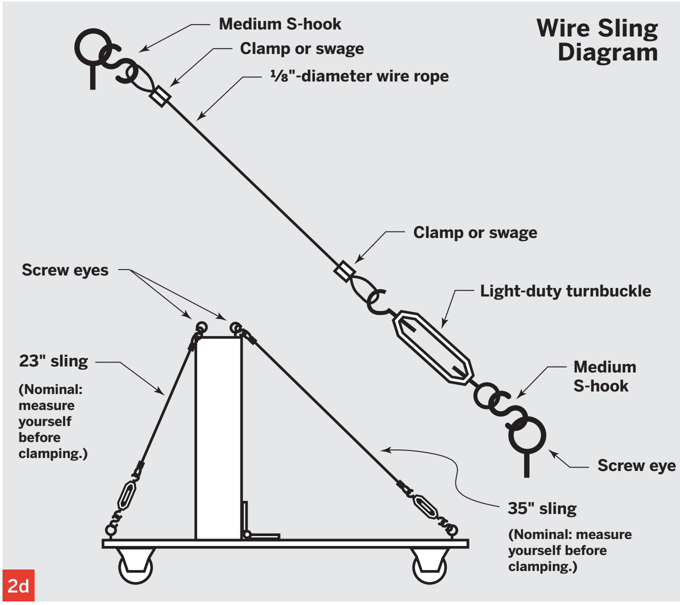
Assemble the rigging as shown in the Wire Sling Diagram using the S-hooks, turnbuckles, and wire rope slings.

2a

NOTE: Check out the placement of the uprights on the deck — each upright is a different distance from the edge. This allows the catapult to be folded compactly for storage.

2b

2c



2d

2d

TIPS: Double-check measurements before cutting, and use locking pliers to grip the wire rope while cutting and clamping.

Tighten carefully — the cables should be taut but not so taut that they bend the screw eyes or damage the deck.

Gregory Hayes (photos); Gerry Arrington (2d)

3. ASSEMBLE AND ATTACH THE ROTATING ARM

3a. Make the counterpoise. Attach two 1" pipe flanges to the counterpoise deck with ¾" wood screws. Connect two 10" nipples, two 90° elbows, two 4" nipples, a tee fitting, and an 8" nipple as shown in the Counterpoise Diagram. Twist all connections together securely.

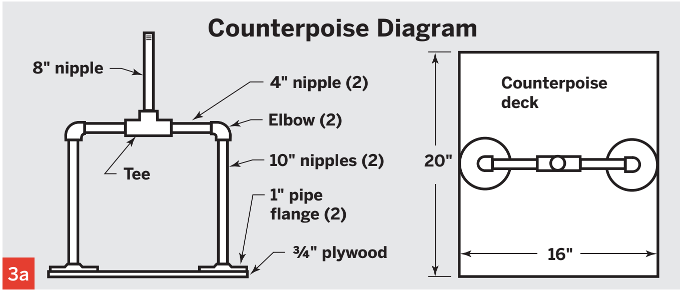
3b. Assemble the throwing arm. Drill a 5⁄16" hole in the center of the pipe cap. Insert a ¼"×2" bolt and tighten with a nut and lock washer. Wrap duct tape over the exposed threads to smooth them.

Next, drill two 5⁄16" holes in the 6' pipe at the ¼"×4" eye bolt locations shown in the Throwing Arm Diagram.

Drill a ⅜" hole through the center of the cross fitting. Insert the 5⁄16"×6" eye bolt and tighten with lock washers and nuts.

3c. Attach the throwing arm and counterpoise to the pivot. Connect the throwing arm assembly to the flanges on the uprights using two 8" nipples, 2 close nipples, and 2 pipe unions. Grease the turning threads.

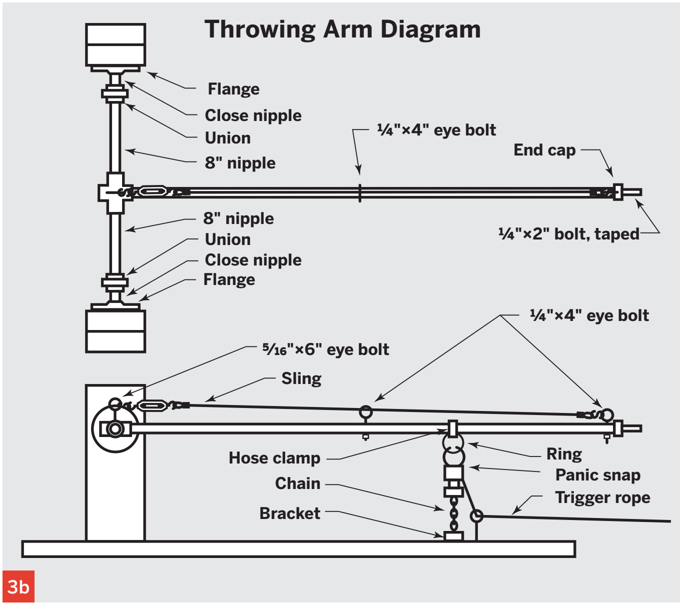
Attach the throwing arm to the cross and assemble the rigging as shown in the Throwing Arm Diagram, using ¼" eye bolts, a turnbuckle, S-hooks, and another wire rope sling. Tighten the wire sling by rotating the turnbuckle.



3a


3a

NOTE: There are 2 separate parts of the rotating arm assembly: the throwing arm and the counterpoise.



3b


3c

TIPS: To save money, we initially used only 1 union (and a 10" nipple) for the main pivot, but this made the throwing arm slower, and harder to remove. Use two 8" nipples and 2 unions instead.

3d. Attach the counterpoise assembly by screwing it into the remaining opening on the cross fitting.

4. MAKE THE TRIGGER

4a. Wrap several turns of the ⅛" cord around the panic snap, tie off, and secure with duct tape.

Place the loop of the panic snap around your finger and pull down on the cord. The panic snap should release easily. If not, reposition the cord and retie.

Attach the panic snap to the throwing arm using the hose clamp and welded ring at the point shown in the Throwing Arm Diagram.

4b. Use #10 round-head screws to install the pipe strap as a support bracket on the center deck as shown. (Here we used a different bracket that came with our brass door chain.)

4c. Measure the distance between the support bracket and the panic snap. Cut the chain or rope accordingly and affix one end to the support bracket and the other end to the panic snap.

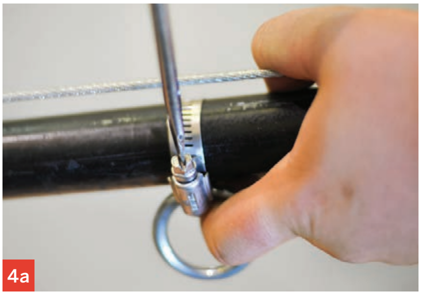
4d. Mount a #4 screw eye on the center deck next to the support bracket. Run the ⅛" cord through the eye so that when pulled it releases the panic snap.


3d

Refer to the Throwing Arm Diagram. You should be able to make the assembly fit perfectly between the 2 flanges attached to the uprights by adjusting the length of the engagement of the unions and the close nipples. However, if there's a problem with the fit, you can reposition one of the uprights.

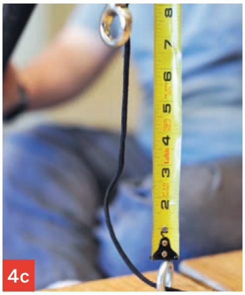

4a

Apply grease to the 2 pipe threads on the cross on which the throwing arm rotates. Make sure connections are solid but turn easily.


4a

Have a helper hold the throwing arm in "ready to fire" position so you can more easily take measurements.


4b


4c


4d

5. MAKE IT MOBILE

5a. Flip the deck over. Position the casters between the reinforcing plates. Drill holes in the deck aligned with the holes in the caster mounting plates. Mount the casters to the deck bottom using 5⁄16" bolts with a washer on each side.

5b. Attach the prop board to the bottom of the center deck with the last 2 door hinges. Fold it down so it supports the deck when the catapult is in use. This prevents rolling during setup and firing.

Mount the L-hook next to the prop board as shown in the Folding Deck Layout Diagram. Rotate the hook to hold the prop board up when moving the catapult.

5c. (Optional) To make the deck even stronger, bolt a 2×4 cross-brace on top of the center deck with a ½" bolt. Rotate it crosswise during catapult use and lengthwise for storage.

6. MAKE IT ACCURATE (OPTIONAL)

Projectiles fly farther and straighter when guided by a smooth channel on the deck. To make a projectile trough, saw a 4' length of 4" PVC pipe in half lengthwise and use deck screws to attach it to the deck directly below the throwing arm.


5a

TIP: If it's easier, mark and drill from the top rather than flipping the deck over and drilling from the bottom.


5b

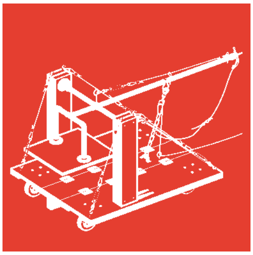

5c

NOTE: Stepping on the deck can damage the strap hinges. To prevent this, bolt an optional 2×4 cross-brace to the center deck.


6

TEST BUILDERS: Brian Melani and Dan Spangler, MAKE Labs

USE IT.



KING OF FLING

⚠ SAFETY NOTES

1. Keep all body parts away from the throwing arm's swing area at all times.
2. Warn downrange bystanders of possible incoming projectiles.
3. Use care when pushing the catapult.
4. Don't step or stand on the deck.
5. Remember that all hinges are pinch hazards. Keep hands and feet clear when folding.

Ready ...

To move the catapult, fold the prop board up and twist the L-hook to keep it in place. Push the catapult to a location with at least 150' of open space to hurl, with no nearby vulnerable targets, such as people, pets, or vehicles. Place the prop board in the down position.

Place up to 120lbs of weight on the counterpoise deck. (Two 60lb bags of concrete mix fit quite well.) If desired, attach two 18" bungee cords to the deck and counterpoise. This will increase the machine's range and capacity.

Aim ...

Point the catapult at the target. Pull the arm down. Latch the panic snap to the firing ring.

Attach a rope or cord to a soft, lightweight test item (plastic dog toys are a good choice). Determining the optimum length of the sling is done through trial and error. Start with a sling length ⅓ the length of the throwing arm and work from there. Be aware that too short a sling will hurl the projectile backward.

Tie a nontightening loop in the free end of the sling (a bowline is perfect) and place the loop over the ¼" bolt protruding from the pipe cap. Center the projectile on the center deck.

Fire!

Make sure the area in front and in back of the catapult is clear. Step 8 or 9 paces to the side. Grasp the cord and pull smartly to release the panic snap. The throwing arm will rotate and hurl the projectile toward the target.

You can optimize performance by making the sling longer or shorter, making the firing pin smoother or rougher, and adding or removing weight from the counterpoise.

Roy Ritchie

⚠ **WARNING: Don't trust the panic snap to hold the arm. Have a helper hold the arm while you latch it, and keep your head and other body parts out of the arm's arc at all times.**

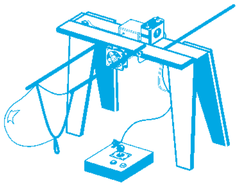
Store It

The Folding Catapult is designed for easy storage. First, remove the weight from the counterpoise deck.

Loosen the turnbuckle on the throwing arm, then loosen and remove the pipe unions on the throwing arm pivot. Remove the throwing arm. Finally, unscrew the pivot assembly pipe stubs from the flanges on the uprights.

Unscrew and remove the counterpoise assembly from the cross fitting.

Loosen turnbuckles and remove the guy wires from the screw eyes, making sure to collect all loose S-hooks. Fold the uprights, and then fold the deck for storage.



GIGANTIC BUBBLE GENERATOR

Arduino-controlled Bubblebot blows enormous, undulating soap bubbles.

By Zvika Markfeld

When I read the Geekcon 2010 call for projects, I thought, what the hack — I'll do it. Inspired by Julia Cameron's *The Artist's Way*, I decided to let creativity into my life, and start inventing things.

I watched Sterling Johnson's magnificent "Giant Stinson Beach Bubbles" clip on YouTube, and when I described it to my neighbor Yuval, he suggested that I combine bubble-making with Arduino, which I had been playing with. Bam! That was all I needed. I submitted the Bubblebot project idea, and it was accepted to Geekcon, where I had the exciting experience of collaborating with all these bright people and watching the design manifest from their suggestions.

People typically blow giant bubbles through a loop of absorbent cord held between two sticks. On my Bubblebot, the sticks attach to a hinged shelf that a gearmotor tilts down and back up by reeling fishing line tied to a lever. After each dip, a servo spreads the sticks and a fan blows air through the loop.

Since Geekcon, I've built two more versions of the Bubblebot, written an Instructable about it, presented it at a local festival, and gotten many great responses to it from both adults and children. I've also learned that making gigantic soap bubbles under diverse wind and weather conditions requires a human touch and intuition that two motors and a fan can't imitate consistently.

I recently added an arcade-style console for remote manual control. Whenever the Bubblebot is switched from automatic to manual mode, a siren sounds to alert everyone nearby that the bot will now be driven by a human rather than by a flawless microcontroller. You have to see people's reactions when this happens.

Zvika Markfeld has been working as a software consultant for the past 10 years and is about to start a new journey: studying industrial design. He likes ridiculous inventions, traveling, programming, cooking, carpentry, gardening, yoga, cats, guitars, and of course, LED contraptions (but who doesn't?).

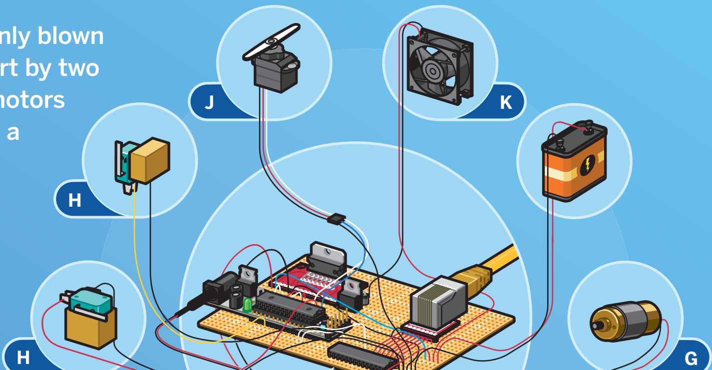
SET UP: p.97 | **MAKE IT: p.98** | **USE IT: p.105**

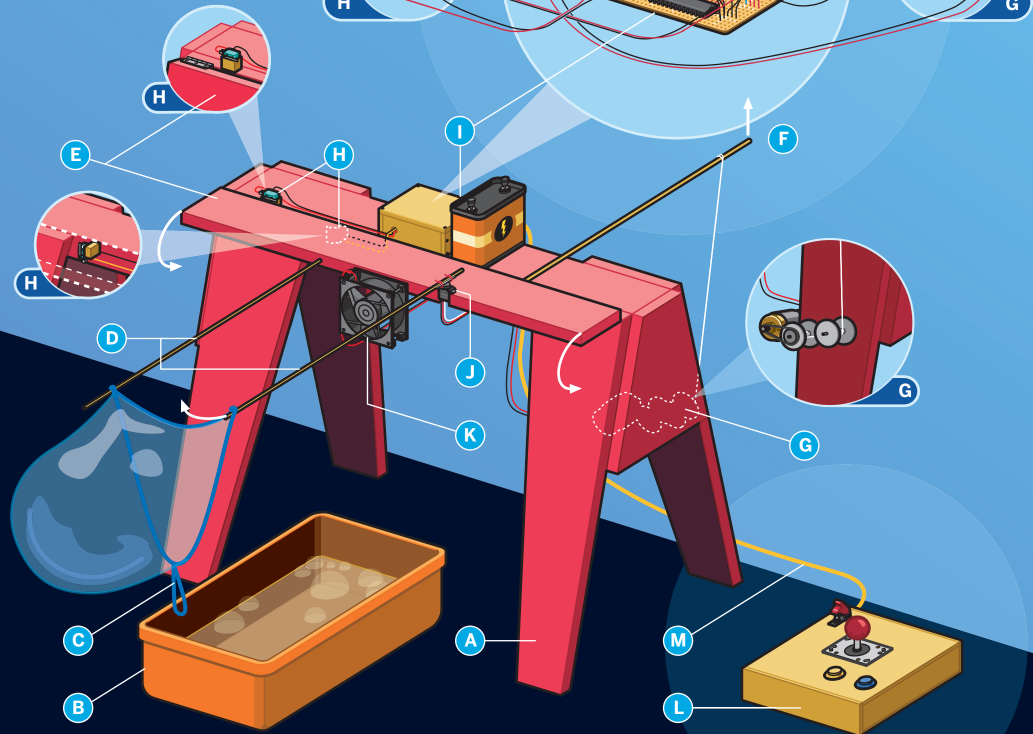
Cody Pickens


COLLABORATE ON
Make: Projects
makeprojects.com

THIN FILM ENGINEERING

Giant soap bubbles are commonly blown through a loop of cord held apart by two sticks. On the Bubblebot, two motors dip and spread these arms, and a fan does the blowing. A microcontroller drives the sequence, in either automatic or manual remote mode.





A The Bubblebot is built on a **sawhorse** or similar frame.

B A **tub of bubble mixture** sits under the frame.

C A **loop of cord** dips into the bubble mixture and spreads apart for blowing.

D Two **arms** (one stationary) hold and move the cord for dipping and blowing.

E The arms are attached to a **hinged shelf**. The weight of the arms and loop makes the shelf naturally tilt down.

F A **tilt lever**, tugged by fishing line, moves the shelf and arms up and down.

G A **gearmotor** drives a spool to reel the fishing line in and out.

H **Feedback switches** trigger when hinged shelf is at the top or bottom of its arc, for input to the microcontroller.

I The **control box** contains an RBBB microcontroller (mini Arduino clone) that runs the servomotor, gearmotor (via an L298N motor controller), and fan (via a TIP122 Darlington transistor).

J A **servomotor** moves one arm close to the other for dipping or away for blowing.

K A **fan** blows air through the cord loop to create giant bubbles.

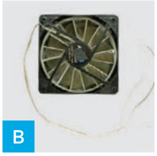
L An **arcade console** enables remote manual control of the motors and fan.

M An **Ethernet cable** connects the arcade console to the microcontroller (via a 16-bit I/O expander chip).

Rob Nance

SET UP.


A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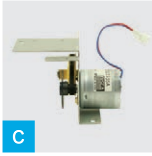
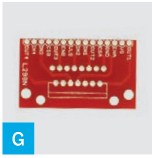
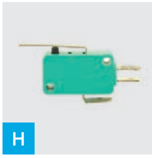

C


D


E


F


G


H

Gregory Hayes

MATERIALS

See makeprojects.com/v/28 for sourcing information.

A. Really Bare Bones Board (RBBB) microcontroller kit, unassembled from Modern Device. This Arduino clone fits the project well because of its size and layout.

B. Computer fan, 12V, tower/rack size the higher CFM the better; it's hard to compete with outdoor wind.

C. Gearmotor, 6V–12V, 5–10 RPM I used a motor disassembled long ago from an old scanner or printer.

D. Hobby servomotor, 13kg/cm torque or stronger

E. Sawhorse or folding A-frame, 2'–2½' tall × 2½'–3' wide. I made my own using lumber, two 1½" hinges, wood screws, and glue.

F. Motor controller chip, dual full-bridge, L298N

G. Breakout board for L298N motor controller

H. Micro switches, momentary SPDT (2)

» **NPN Darlington transistor pair, TIP122G**
» **Spool** to attach to the gearmotor. I used a plastic solder spool.
» **Voltage regulator, 5V, 7805**
» **1N002 diodes (1–6)** Connect as many as needed in series between your 12V power (–) and the L298N chip's VS pin to drop the voltage to whatever runs your gearmotor best.
» **1N004 diode**
» **Resistors, 100Ω (2)**
» **Insulated wire, 18–22 gauge, assorted colors, about 20'**
» **Breakaway header, 1×40 pin**
» **Heat-shrink tubing or electrical tape**
» **Servo cables, 3-pin, 12" (10)** or enough to chain together for 10'
» **Project box, about 7"×5"×3"** to hold circuit board
» **Stripboard or perf board, about 5"×3"** to fit into project box
» **Battery, 12V**
» **Barrel connector, 5mm**
» **Dimensional lumber, 1×4, 12" or longer** for the shelf
» **Hinges, 1½" long (2)** with mounting screws
» **Wood dowels, ¼" (6mm) × 2'–3' long (2)** or other strong, lightweight rods, for the cord holding arms
» **Wood dowel, ⅜" (8mm) × 3' long** for the tilt lever; cut to size after installation
» **Cord, yarn, lace trim, or thick cotton string, 6'** should be flexible, absorbent, and not prone to breaking or twisting into knots
» **Fishing line, monofilament, 6'**
» **Machine screws with nuts** as needed to mount servomotor to frame, and/or spool to gearmotor
» **Wood screws: 1" and ½"** as needed to mount your fan, gearmotor, project box, and joystick
» **Zip ties: 10" (12+) and 4" (12+)**
» **Plastic tub, 4gal (approx.)** to hold soap mixture
» **Wood glue**
» **Oil or grease**
» **Lamp cord and screw terminal block connector, 2×2 (optional)** for connecting large 12V battery
» **Thin copper wire (optional)**
» **Paper or cardstock, and tape (optional)** for duct

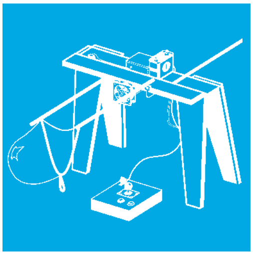
For the bubble mixture:
Experiment with this recipe as needed.
» **Distilled water, 1gal (4l)**
» **Bubble solution, 1gal (3.2l–4l)** from a toy shop or online
» **Dishwashing liquid, 14oz (400ml)**
» **Liquid glycerin, 14oz (400ml)** available from drug stores, natural foods stores, or online

For the arcade console (optional):
» **Plywood, ¼"–⅜" thick (7mm–10mm or so), 3'×1'**
» **Pushbuttons, arcade style, OBSF (2)**
» **Switch, toggle, with safety cover**
» **Joystick, arcade style, 4-way digital** i.e. on/off, rather than variably sensitive
» **I/O expander chip, 16-bit, MCP23017** Get the MCP23017-E/SP through-hole version rather than a surface-mount package.
» **Connectors, female (aka jacks), RJ45 (Ethernet), with PCB mounting posts (2)**
» **Breakout boards, RJ45 (2)**
» **Cable, RJ45 (Ethernet), 6'**
» **Speaker, ¼W**

TOOLS

» **Handsaw**
» **Razor saw**
» **Cordless drill and bits**
» **Hole saw, 1" (27mm)**
» **Wire cutters and strippers**
» **Ruler**
» **File**
» **Scissors**
» **Soldering iron and solder**
» **Glue gun and hot glue**
» **FTDI-to-serial programming cable/ adapter** for programming the RBBB
» **Computer with internet connection**
» **Pliers and wrench (optional)** for disassembling arcade console joystick
» **Protractor (optional)** for setting angle of fan mounting holes

MAKE IT.



BUILD YOUR BUBBLEBOT

Time: A Weekend
Complexity: Moderate

1. SET UP THE FRAME

1a. Start with a sawhorse or similar frame. Take the 1×4 shelf, measure about a third of the way down from the right side end, and saw a rectangular notch that exactly fits your servo body lengthwise. The servo will hold one of the cord sticks, and we'll call this edge of the shelf the front.

1b. Attach 2 hinges along the back edge of the shelf, one at each end. Similarly attach the other sides of the hinges to the top of the sawhorse's crossbeam, making sure that the shelf can swing 90° down — from flat horizontal to perpendicular to the ground.

1c. Along the front edge of the shelf, drill 2 pilot holes in the middle for attaching the fan, and another hole just past the fan mounting holes (opposite the servo notch) sized for the fixed cord arm. In the back edge of the shelf, drill a hole sized for the tilt lever about 2" from the end nearer the servo notch.

1a

NOTE: It probably makes more sense to buy a sawhorse, unless you enjoy just about any kind of woodworking (like me) — in which case, see makeprojects.com/v/28 for how I built mine.

1b

TIPS: Drill pilot holes for the screws to prevent the wood from cracking.

1c

Mount the fan angled down somewhat, so that it blows underneath the arms where the loop will hang.

2. ADD BUBBLING SUBSYSTEM

2a. Place the servo in its notch, drill pilot holes for the supplied screws, and screw securely in place.

Level the servo with the shelf so that when it tilts straight down, the servo arm is oriented up and down, parallel to the shelf.

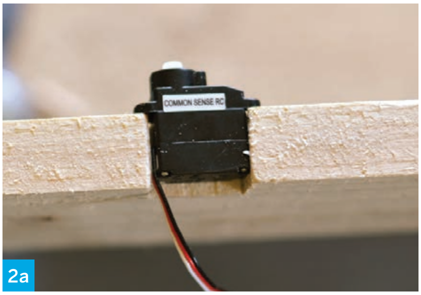
2b. Fit one of the cord arms into its hole in the front of the shelf. Attach the other cord arm to the servo arm using short zip ties. Instead of zip ties, you can wind thin copper wire around the joint.

2c. Cut the cord into lengths of 2' and 4'. You can make minor size adjustments later on, but these numbers should put you in the safe zone.

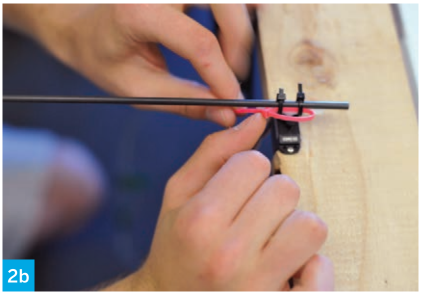
2d. Loosely tie one end of each cord to the free endof each cord arm. Make sure you can untie the ends later for adjustment. Now, when the shelf is parallel to the ground and the arms are open, the cord should hang in a loose triangle.

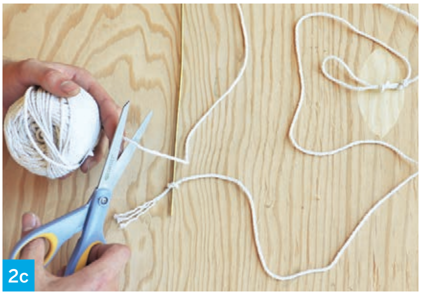
Make a loose knot or tie a zip tie to the middle of the long cord, creating a smaller loop at the bottom of the main, larger one.

This small loop will help the main loop make its way back into the bucket when the arms tilt down, to prevent it missing the bucket and getting dirty (which weakens bubble formation).



2a


2b


2c


2d

TIP: For extra reinforcement (or if screws weren't supplied), you can attach the servo using bolts or machine screws with matching nuts and washers. Just drill through-holes and use a washer on each side of the shelf.

NOTES: The cord arms and tilt lever should fit snugly but not tightly. And don't use wood glue anywhere just yet — leave it until the end.

Servos are designed for controlling R/C airplanes via metal hooks, and their physical arrangement can be awkward for other applications. Just do the best you can to get a firm connection between servo arm and cord arm.

If needed, you can tie a washer or other small weight to the bottom of the small loop.

2e. Fit the tilt lever into its hole in the back edge of the shelf and tie the piece of fishing line to its free end.

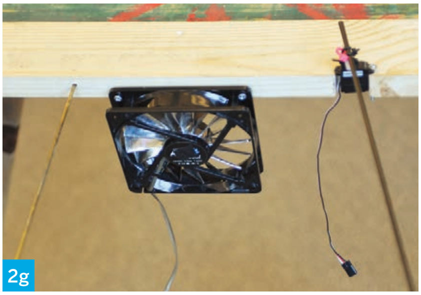

2e

TIPS: **It helps to file a small groove in the dowel to keep the fishing line knot in place.**

2f. Pull on the fishing line to manually test how much force it takes to pull the shelf (with arms attached) up to its topmost, horizontal position. It shouldn't be too hard. The shelf should also fall down by itself if you let go. If not, make sure your hinges are properly aligned and oil them a little bit.


2f

2g. Attach the fan to the front of the shelf using 1" wood screws. When the shelf is in its topmost position, the fan should point right into the middle of the cord triangle.

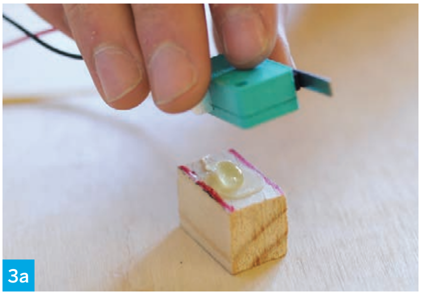

2g

You may need to adjust the fan angle later, so don't drive the screws in all the way yet.

3. ADD SWITCHES AND MOTOR

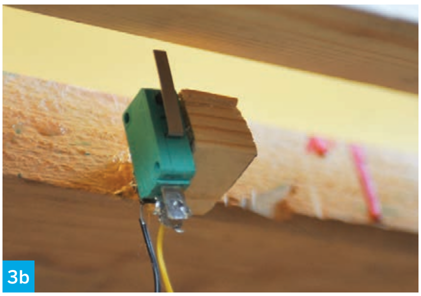
Two micro switches act as limit switches for the hinged shelf, reversing the shelf's direction when it reaches the top or bottom of its arc.

3a. Solder 2' wire leads to the ground and NC terminals of one micro switch, and to the ground and NO terminals of the other. Hot-glue the NC-connected switch on top of the sawhorse's crossbeam so that when the shelf swings up, it clicks the switch just before it reaches the top.


3a

To get the micro switch positions right, it helps to glue them to small brackets cut from scrap wood rather than directly to the crossbeam.

3b. Hot-glue the NO-connected micro switch to the underside of the crossbeam so it clicks when the shelf hangs all the way down.


3b

3c. Attach the spool to the gearmotor shaft. Mount the gearmotor to the back leg of the sawhorse on the lever side with the motor shaft parallel to the hinges.

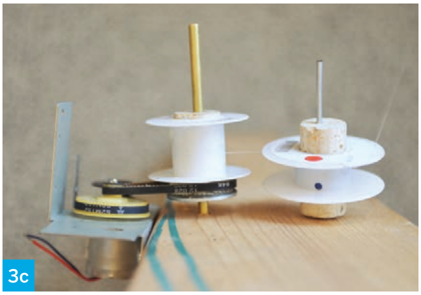
3d. Solder a 3' wire to each gearmotor terminal, then tie the free end of the fishing line around the spool (the other end should already be tied to the tilt lever) and hot-glue it down so it doesn't slip.

4. ADD THE ELECTRONICS

4a. Assemble the RBBB (Arduino clone) kit according to the supplied instructions, but substitute a 7805 voltage regulator for the included L4931CZ50 regulator in the spot marked "VR." Solder the L298N motor controller to its breakout board.

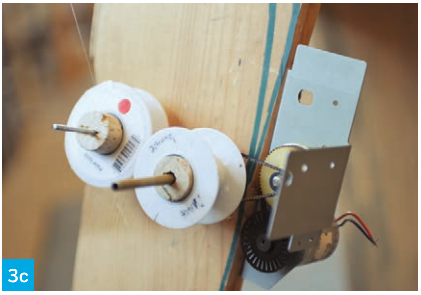
4b. Plug the RBBB into the stripboard, perpendicular to the strips underneath. Use pin headers to solder the L298N breakout board alongside it so the Arduino D6 and D7 pins connect to the L298N IN2 and IN1, respectively.

4c. Insert the MCP23017 16-bit I/O expander chip alongside so RJ45 pins 2–8 line up and connect with the I/O chip's pins 1–7 in reverse order (e.g. RJ45 pin 8 to chip pin 1, RJ45 pin 7 to chip pin 2, etc.). The I/O chip's pins 12 and 13 will connect to Arduino pins A5 and A4.



3c

NOTES: The characteristics of the motor and spool that you use will dictate how you should mount them. Use your hacksense to come up with a good arrangement. You may need to add brackets, rollers, or other extra components.



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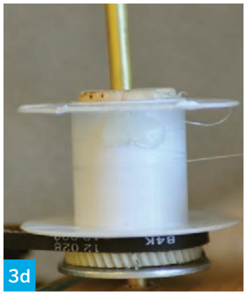

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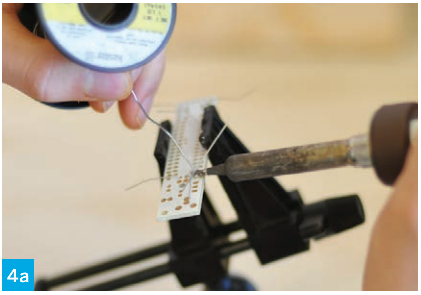
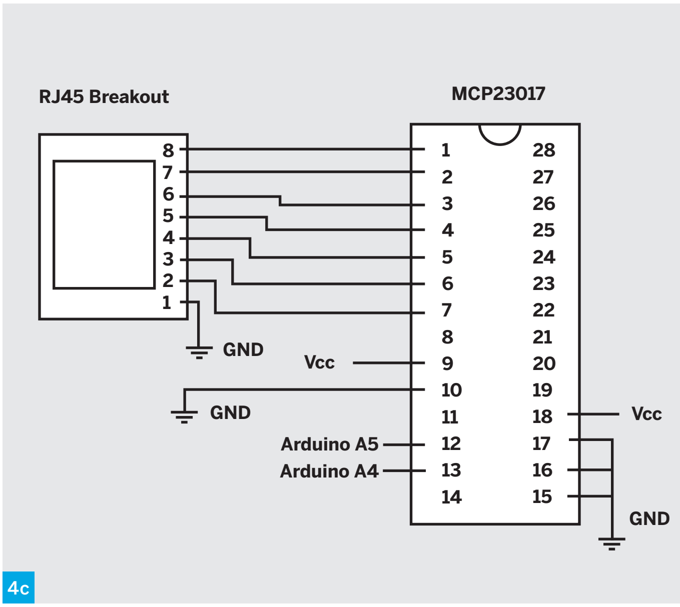


4a

If you're making the arcade console, fit an RJ45 jack onto an RJ45 breakout board and solder pin headers to plug it into another corner of the stripboard, so that an Ethernet cable can plug in at the board's edge.



4c

4d. Follow the schematic and photos to plug the rest of the onboard components into the stripboard and connect them together: the resistors, diodes, and Darlington transistor.

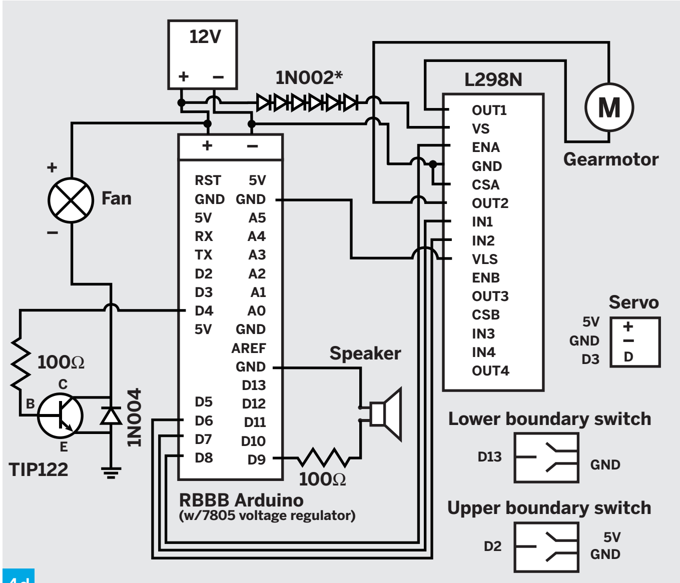
Drill away the copper connections at all points marked with an "X", and between the RBBB and I/O chip pin rows.

4e. Drill holes in the sides of the project box for connecting the off-board component wires, battery power, and Ethernet cable to the arcade console (if using).

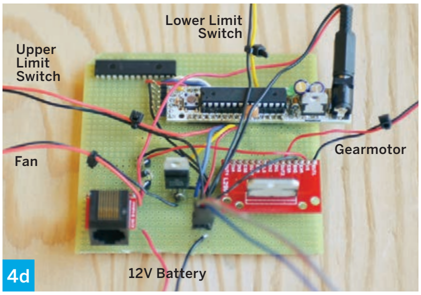
4f. Follow the schematic to solder wire connections out to all the off-board components, and thread the wires through the holes: gearmotor, servomotor, fan, speaker, boundary switches, and 12V battery.

4g. (Opposite) Secure the board inside the box using zip ties, making sure that an Ethernet cable can both plug in and unplug from the RJ45 jack. Connect all the off-board components to their leads.

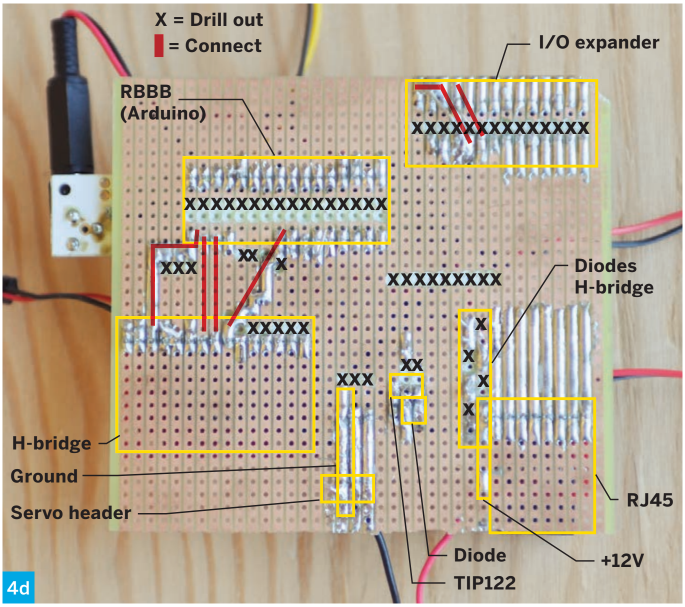
4h. (Opposite) If your battery is small, you can use hookup wire to connect it to your board. With a larger one (like a moped battery), use a switched lamp cord, screwing its wires to one side of a 2×2 terminal block on the board. The other side of the block should connect to a standard 5mm barrel connector for plugging into the RBBB power jack.



4d



4d

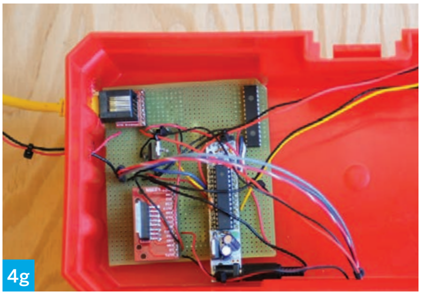


4d

4i. To connect the servo, I used a 10' chain of 3-pin servo extension cables rather than plain wire, which lets you easily disconnect and reconnect the motor properly, following the color scheme power=red, ground=black, control=white/yellow.

4j. If you want to connect the speaker, wire it between Arduino pin D9 and GND. With the speaker connected, the siren will play constantly while Bubblebot is in manual (controller) mode.

4k. Attach the project box to the sawhorse top. If you're unsure of its placement, use zip ties for now and substitute screws later.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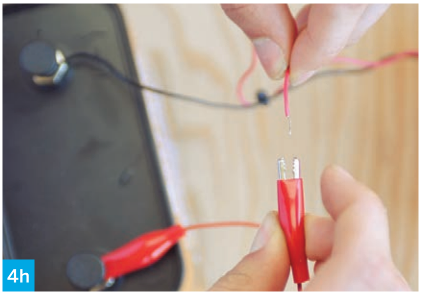
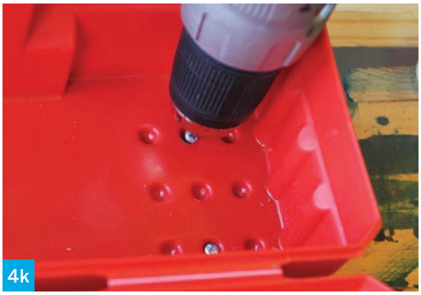

4h


4k

5. BUILD THE REMOTE ARCADE CONSOLE (OPTIONAL)

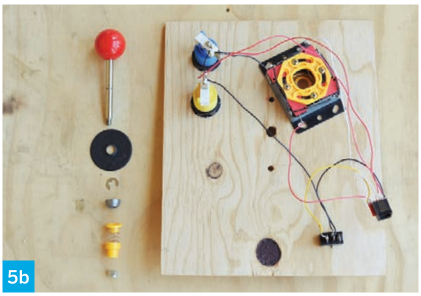
You could make the Bubblebot without the console, but you wouldn't want to, because it's the coolest part!

5a. First, cut 6 pieces of plywood for the box: 25cm×27cm (2); 25cm×7cm (2); and 16.5cm×5.5cm (2).

5b. On one of the large pieces (the top panel), drill a hole for mounting the switch and 2 holes for the buttons, then cut a rectangular hole in the middle for the joystick.

Install the switch and the buttons with the supplied nuts, and mount the joystick with ½" screws.


5a


5b

NOTES: These instructions cover 7mm plywood — with other widths you'll need to tweak these numbers a little bit.

MAKE's test builder Max Eliaser used ¼" plywood with the following specs: 2 pieces 10"×12", 2 pieces 12"×2¾", 2 pieces 10"×2¼", and 2 scraps 2"×2¼".

Feel free to use my layout (makeprojects.com/v/28) or create your own. I used a 5⁄16" (8mm) bit for the switch, a 1" (27mm) hole saw for the buttons, and a razor saw for the joystick.

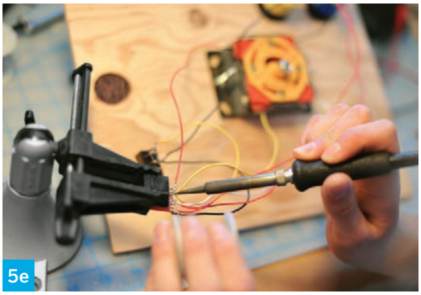
5c. Cut a small rectangular hole in one of the side panels, just large enough to fit around an RJ45 jack.

Glue all the wood pieces together except for the top panel to make an open box.

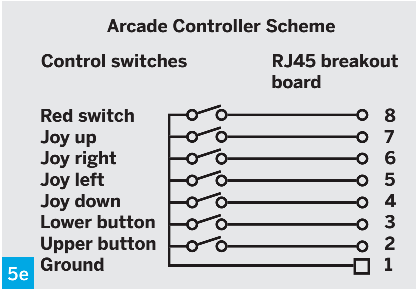
5d. Under the top panel, solder a ground wire (or wires) to connect the ground/common terminals of all the buttons and the toggle switch, and one leg of each joystick direction.

5e. Solder individual wires to the power-side contacts for all the controls (with 3-pin buttons, solder to the normally open pin). Solder an RJ45 jack to an RJ45 breakout board, then connect all the wires to the board as shown in the schematic.

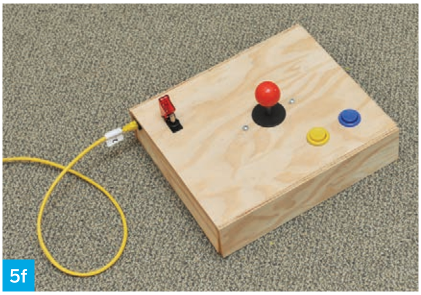
5f. Glue the RJ45 jack into the hole you cut for it in the side of the box, then close the box.



5e



5e



5f

NOTES: These pins will all be pulled up by the MCP23017 16-bit expander chip and will read `HIGH` on the Arduino when not activated.

For covered switches with built-in LEDs and 3 pins, ignore the ground pin and solder leads to the Power and ACC pins. The LED won't light up, but the switch will still work.

Voilà! You've just built a multipurpose arcade console that you can use in many projects to come.

TEST BUILDERS: Max Eliaser and Tyler Moskowite, MAKE Labs

6. PROGRAM AND TEST

6a. Download and install the Arduino environment (from arduino.cc) if you don't have it already.

Download the project code files *BubbleBot_MAKE* and *ArcadeControllerTester* from makeprojects.com/v/28.

Plug the programming cable between your computer and the microcontroller, and upload the *BubbleBot_MAKE* sketch.

6b. First, test the Bubblebot in automatic mode. Disconnect the programming cable and power up the Arduino to do a dry run without bubble mix.

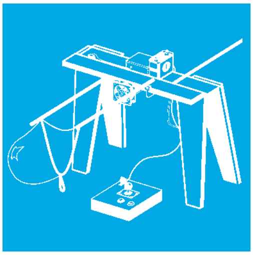
Watch the arms and do a program-test loop, modifying the servo boundary values `arm_open_pos` and `arm_closed_pos` at the top of the code, until the cord loop dips fully into the container and stretches out into a nice triangle.

6c. To test the arcade console (if you made one), plug the cable between it and the control box. Connect the RBBB to your computer and upload the *ArcadeControllerTester* sketch.

Open the Serial Monitor and try out all the controls while watching the Serial Monitor outputs. The outputs should match the control inputs; for example, you should see `UP` when you push the joystick up.

Congratulations, you've made it. Enjoy!

USE IT.



BLOW IT BIG TIME!

Cody Pickens

Bubblebot Operation

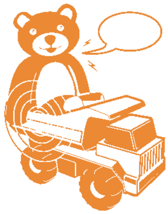
Combine the ingredients for the bubble mixture and let it stand for 24 hours, ideally in a refrigerator. Fill a tub, place it below the Bubblebot, and power it up.

Watch how it works, and make adjustments by modifying the source code (speed and duration of arms spreading, number of spreading iterations), by raising or lowering the tub, or by setting up in different locations.

Tips for Happy Bubbling

» Pick a humid day, as cool as possible.
» Avoid direct sunlight on the bubbles.
» Pick places with steady wind flow or operate indoors. If you want to try for stronger wind, substitute a car fan for the computer fan, and experiment with different fan positions.
» To focus the air more efficiently into the cord loop, add a paper duct in front of your fan. Just roll up and tape a piece of printer paper or cardstock about the same size as your fan's blade circumference, then tape this duct to the fan.
» Decorate your Bubblebot! I added color to mine by slitting foam pool noodles along their length, about ⅔ of the way deep, wrapping them around the sawhorse legs, and securing with zip ties. I cut and applied more noodle foam to other wood surfaces using hot glue.

Thanks to Jonatan Bien and Uri Kareev for helping me build the first version of Bubblebot, and to my good friend Moria Lahis, who is not only a great photographer but also a source of inspiration for creativity and happiness.



CHARLIE'S BEAR

Make a plush toy that talks to other objects — and you.

By David Harris

This location-aware teddy bear reads RFID tags and plays different customizable sounds depending on where it is or what object it's near — other toys, books, CDs, anything.

Charlie's Bear helps children explore the world around them by producing sounds in reaction to other toys or objects nearby. It can play any sound files you upload to the memory card inside — for example, the voice of the bear, a noise that another toy might make, a theme song prompted by a toy from a TV show, or a reading of a favorite book.

I created the toy for my nephew Charlie, who was born with cerebral palsy. Charlie's vision is poor, but he's very tactile and auditory. This toy takes advantage of his excellent hearing and the joy he derives from music and sounds. And for all young children, this toy is an easy and safe way for them to pick their own music. Just bring a CD case (or other tagged item) near, and the bear plays it — no complicated CD player or computer.

At the heart of Charlie's Bear, an Arduino microcontroller uses a radio frequency identification (RFID) reader to recognize nearby RFID tags, then uses an audio shield attachment to play corresponding audio files stored on an SD memory card. The SD card stores about a minute of audio content per megabyte, so a cheapo 4GB card will hold more than 60 hours.

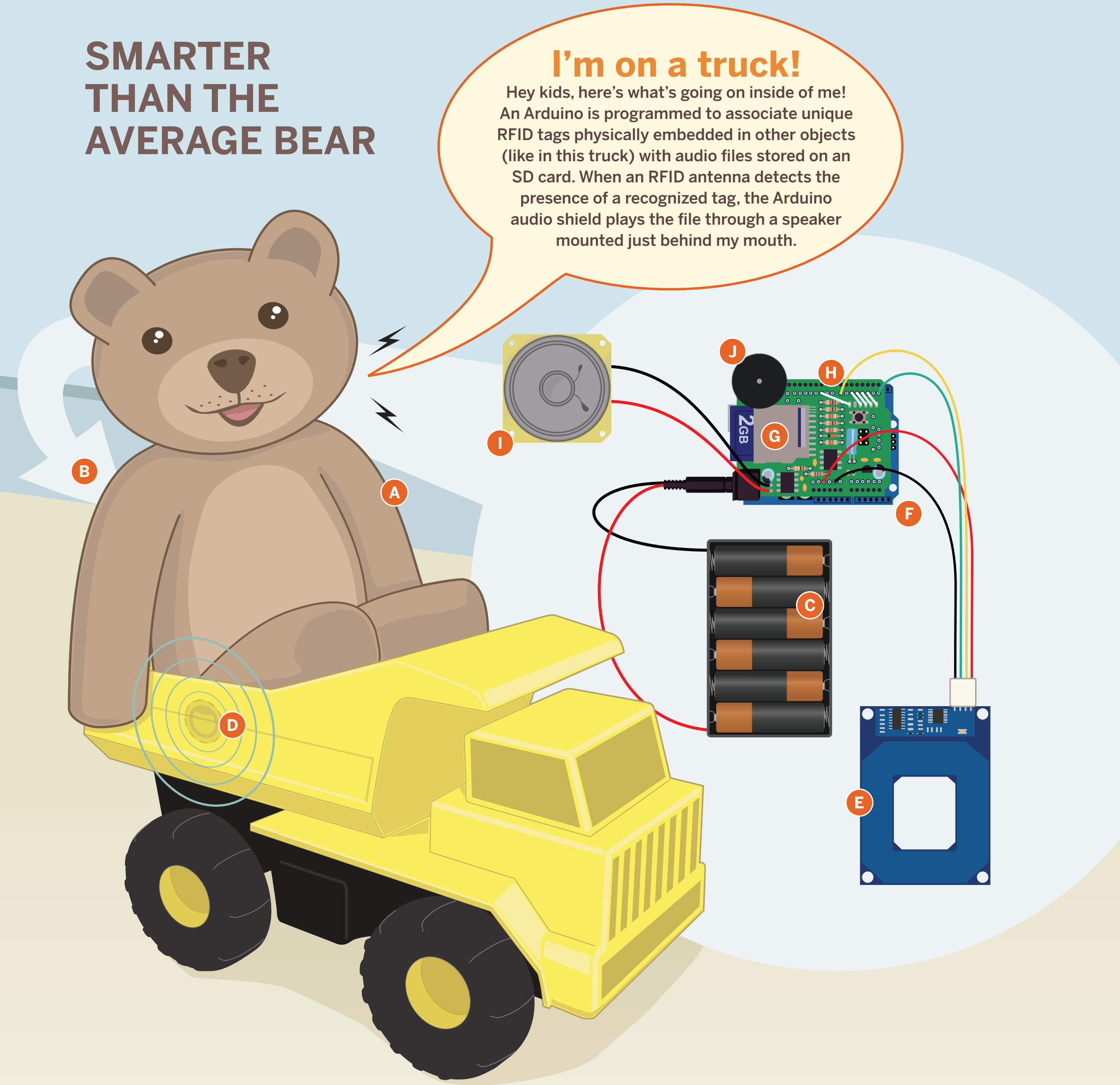
David Harris (@physicsdavid) is a science communication designer based in Palo Alto, Calif. He is a co-organizer of Science Hack Day San Francisco and a keen maker of embedded electronic devices.

SET UP: p.109 | MAKE IT: p.110 | USE IT: p.114

Kathryn Roach


THE MYSTERY MEN OF MARS
CARL H. CLAUDY
MEN OF MARS
CARL H. CLAUDY
G&D
GROSSET & DUNLAP
Adventures in the Unknown
Weird! Mysterious! Incredible! Astounding!
CAN SUCH THINGS BE?
THE MYSTERY MEN OF MARS
A THOUSAND YEARS A MINUTE
THE LAND OF NO SHADOW
NIMMO
BOOK MA

SMARTER THAN THE AVERAGE BEAR



A **Teddy bear** (or other plush toy) houses the electronics and provides a lovable identity for embodying the electronics' behavior.

B A **velcro closure** in the teddy bear's back lets you insert the electronics and change the batteries.

C Six **AA batteries** supply power.

D **RFID tags** embedded in household objects or toys each carry a unique 10-digit hexadecimal code.

E **RFID antenna** inside teddy detects nearby tags and reads their code.

F **Arduino microcontroller** monitors the RFID antenna for a signal, and looks up *.wav* filenames associated with any tags detected.

G **SD memory card** stores audio files in *.wav* format for playing.

H **Arduino audio shield** plays *.wav* files returned from the RFID tag lookup.

I **Speaker** generates sound from the audio shield's signal output, giving the bear a voice.

J **Volume control** is left off the Arduino shield, so that playing with the toy can't accidentally turn it down. (The volume will be set at or near the maximum.)

Tim Lillis

SET UP.

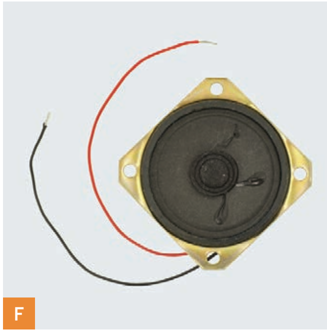

A


B

C


D


E


F

MATERIALS

RFID Teddy Bear Project Bundle available from Make: Projects (makeprojects.com/v/28). Includes all materials below except stuffed toy and velcro.

A. Stuffed toy Choose something quite soft that can accommodate the electronics easily and also provide some padding for them.

B. Arduino microcontroller

C. Wave Shield an audio shield for Arduino, sold as a kit from Adafruit Industries

D. RFID card reader, serial aka RFID antenna, from Parallax Inc.

E. RFID tags, 125kHz, one for each object you have audio files for Parallax offers several different shapes/sizes.

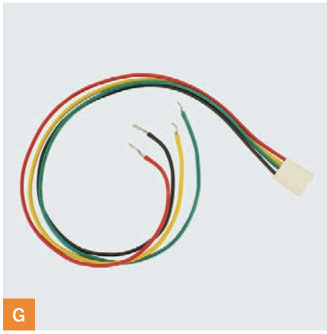
F. Speaker, 3"

G. Connector header, female, 4-pin, 0.1" spacing, with 4 jumper wires Or use a 4-pin female connector cable and cut off one end.

» **Wire, 22 gauge, solid** multiple colors
» **Velcro** that matches toy color
» **Thread** that matches toy color
» **Barrel connector, size M (5.5mm outer × 2.1mm inner)** power plug for Arduino
» **Battery holder, 6×AA**
» **Rechargeable batteries, AA (6)**
» **SD memory card**
» **Battery clip for 9V battery (optional)** if battery holder has 9V connector rather than wire leads

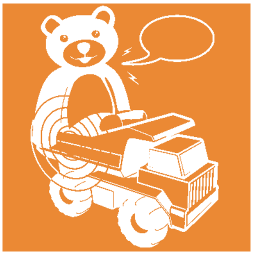
TOOLS

» **Soldering iron**
» **Solder**
» **Phillips screwdriver**
» **Wire cutters and strippers**
» **Scissors or X-Acto knife**
» **Sewing needle**
» **Tape, electrical**
» **Marking pen, permanent**
» **Computer with internet connection**
» **USB programming cable for Arduino**
» **SD memory card adapter** if your computer doesn't have a built-in SD slot


G

Gregory Hayes

MAKE IT.



BUILD YOUR OWN CHARLIE'S BEAR

Time: 1 Day
Complexity: Easy

1. ASSEMBLE THE ELECTRONICS

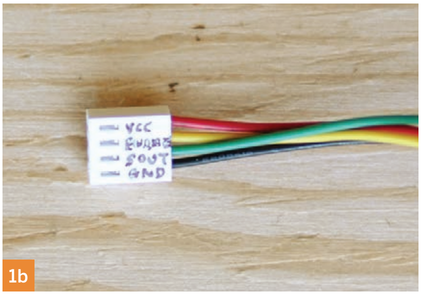
1a. Solder the Wave Shield together, following the instructions at ladyada.net/make/waveshield. At the step where you screw the plastic volume dial onto the housing, just insert the screw without the plastic dial, and turn it to maximum volume level.

1b. Cut and strip 4 wires about 6"–8" long, and solder them to the 4-pin connector, leaving the other ends bare. Mark the connector positions Vcc, Enable, SOut, and GND, to match the RFID reader's serial header, and connect red and black wires to voltage and ground, respectively.

1c. If your battery holder has wire leads, solder its red wire to the inner terminal of the barrel connector (power plug) and its black wire to the outer terminal. (If it has a 9V connector, solder the wires from a 9V battery snap.)

Screw the housing onto the plug and wrap the wires with electrical tape if needed to hold things firm. Solder the wires to the 9V battery clip and insulate with more tape.

1a



1b


1c

NOTE: The length of the wires isn't critical, but leave enough room to place the RFID sensor in the bear's chest and have the wires come out the back to reach the rest of the electronics.

1d. Solder two 6" wires to the speaker if it doesn't already have leads connected.

1e. Solder the speaker wires to the 2 holes on the Wave Shield right next to capacitor C9, behind the headphone jack. Either wire can go in either hole.

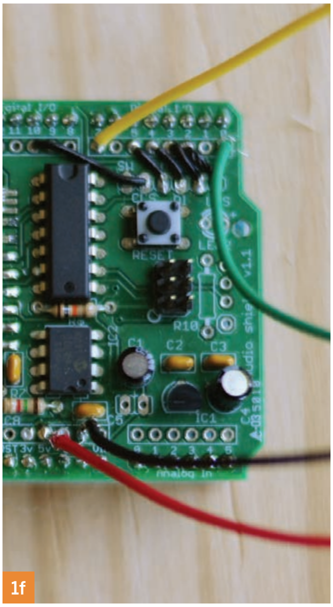
1f. From your 4-wire RFID connector cable, attach the red and black wires to the Wave Shield's +5V and GND holes, respectively, and solder the SOut wire to digital I/O pin 0 and Enable wire to pin 7.

1g. To complete the electronics, just plug the Wave Shield onto the Arduino, connect the 4-wire cable to the RFID reader (make sure it goes the right way around), and plug the battery power plug into the Arduino.

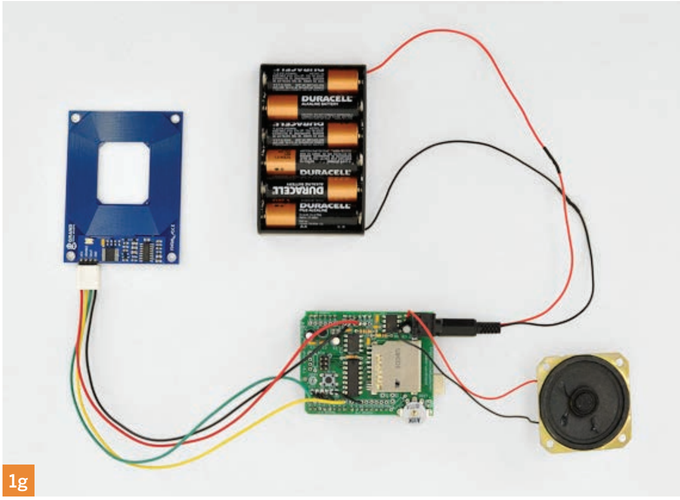
2. DETERMINE THE RFID TAGS' IDS

2a. Install the Arduino environment (arduino.cc) if you haven't already, and download the Charlie Bear software *CharlieBear.pde* and RFID tag identifier *RFIDread.pde* from makeprojects.com/v/28. Unplug the RFID reader. Open *RFIDread.pde* and upload to the Arduino using a USB cable.

1e



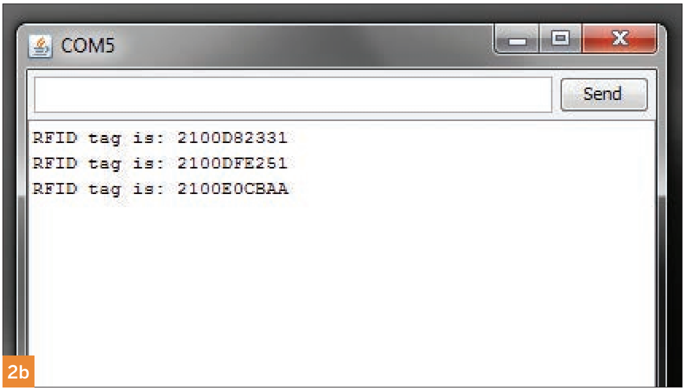
1f



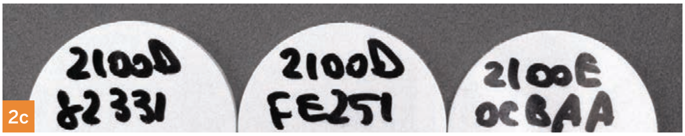
1g

2a

2b. Open the Serial Monitor to see what the RFID reader is seeing, then plug the RFID reader back in. Bring each one of your RFID tags close to the reader. The 10-digit hexadecimal tag IDs should print out in the Serial Monitor.

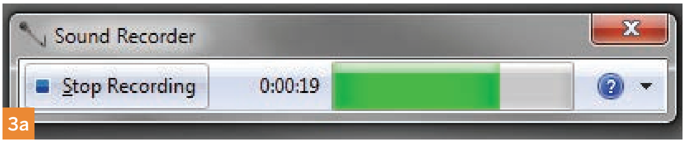


2c. Use a permanent marker to label each tag with its tag ID. You won't need to do this again until you get a new batch of tags.

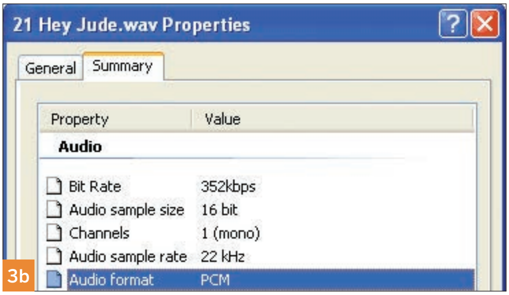


3. ENCODE THE AUDIO

3a. For each tag, record your audio or otherwise obtain a sound file you want to use.

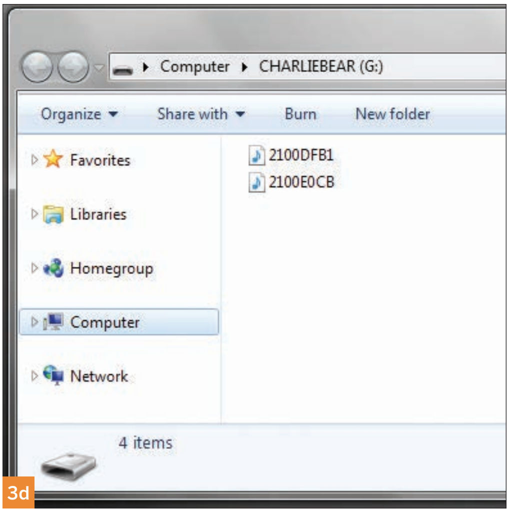


3b. Download and install Audacity (audacity.sourceforge.net) — free, open source software for recording and editing sounds. Following the Wave Shield's "Converting audio to the proper format" tutorial, use Audacity to convert your audio files into the correct format: 16-bit sample size, PCM encoding, and a sample rate of 22kHz or less. These conversions might be the trickiest part of the whole project.



3c. Name each sound file with the first 8 hexadecimal digits of the RFID tag you want to associate with it. (It's extremely unlikely that you'll have duplicates.)

3d. Copy the sound files in the root directory of the SD memory card.



TIP: Since these filenames don't say anything about the sounds they contain, be sure to note somewhere which sound goes with which tag.

4. CONFIGURE AND TEST THE CODE

Unplug the RFID reader and load the *CharlieBear.pde* sketch into the Arduino.

Plug the RFID reader back in, and see if bringing a tag near starts a sound playing.

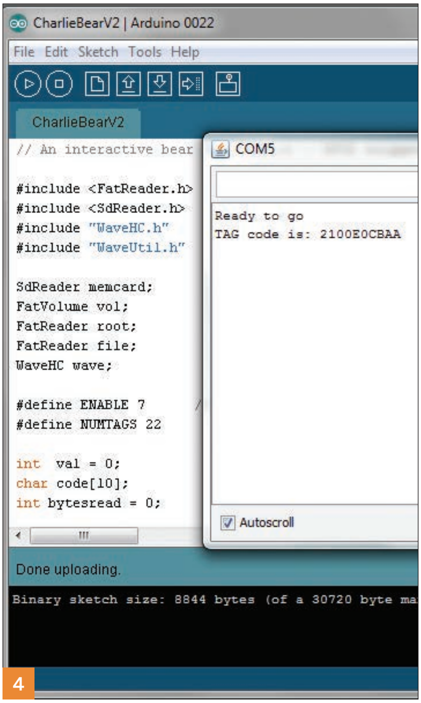
5. PERFORM THE PLUSH TOY SURGICAL IMPLANT

5a. Make a spinal incision in your bear or other plush toy large enough to get your electronics inside. How you perform this operation will depend on how the toy is made. For mine, I unstitched the bear along its backbone seam from just below the neck down to the waist.

Attach a closure mechanism. I sewed velcro of a matching color inside one side of the incision and on the outside of the other. There was enough play in the bear's "skin" to allow the sides of the seam to overlap and the velcro to shut.

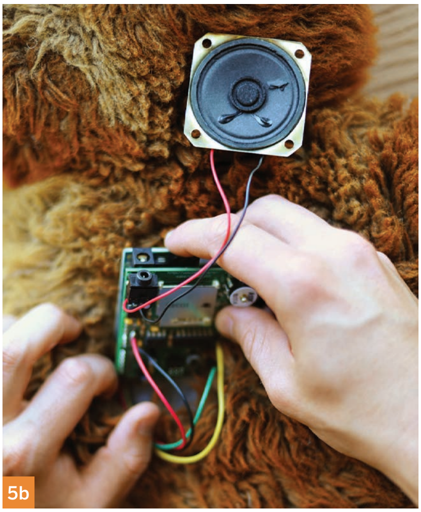
5b. Embed the electronics. Put the speaker behind the bear's mouth and nose. The RFID reader should go against the chest, and the rest of the electronics can go anywhere inside the middle of the bear. Take some stuffing out if it's hard to close the bear.

Your toy is ready to play with!



4


5a


5b

TROUBLESHOOT YOUR CODE:
If there is no sound, check:
- the power connections
- that the RFID connector is oriented the right way
- that your sound files are named correctly and are in the correct format.

If you still experience problems, debug them by running the electronics while the Arduino is cabled to your computer, and watch the Serial Monitor for what the RFID reader sees and sends. For more help, see the comments at the top of the code.

NOTE: There are many ways to reclose your bear, but you'll want to be able to get back inside, so don't just stitch it up. I recommend using velcro (not the adhesive kind). The main thing is to come up with something that a child can't open easily or by accident.

TIP: If you know the stuffing isn't conductive (which it shouldn't be), you can just put the electronics straight in. But you may get fluff everywhere, so be careful when taking the memory card in and out. I've never encountered stuffing that conducts electricity, but if yours does, try enclosing your components in the anti-static bags they probably shipped in.

TEST BUILDERS:
Paul Mundell and Tyler Moskowite, MAKE Labs

USE IT.

CHARLIE'S BEAR LOVES TO PLAY!

Connecting Sounds with Objects

Combining object sensing with sound is more powerful than you might think. The most obvious application is just for the bear to make appropriate noises in response to other toys. But what about interacting with other objects, besides toys? An ID tag stuck inside the cover of a book can trigger the bear to read it. A tag in a CD case can trigger the bear to play the corresponding music, without a small child's having to fuss with smudge- and scratch-prone CDs or age-inappropriate computers.

If you have a child who just won't listen to you, maybe they'll listen to their friend the bear. Record some tags in "bear voice" saying that it's time to go to sleep or time to brush our teeth. And don't forget to give the parents a keychain RFID tag that has no sound associated with it. This very handy tag will instantly make the bear go silent! These are some of the Charlie's Bear sound applications I've used successfully with the kids in my life, and I'm sure you can come up with many more.

Mod Charlie's Bear!

The software for Charlie's bear is fairly straightforward and easy to modify. For example, the existing code interrupts the current sound playing when a new tag is brought into range, but you can change its behavior so that it plays the current sound file until the end before starting the new one.

There are a few obvious physical modifications you might like to try. The bear has no power switch, so to turn it off you need to unplug the battery pack. Instead, you could add a switch inside a paw or combination of paws.

Kathryn Roach

Alternatively, you might like to add some kind of motion-sensitive switch and modify the code so it uses less power when idle. With software power management, turning off the RFID antenna will save the most power. Then the batteries will last long enough that you might never need to switch your bear off.

Or maybe the bear would like to dance along with the sounds it makes? Consider adding a vibration motor or stepper motors that the Arduino can trigger along with the sound files. Perhaps you can modify the code so that some tags play sound and others cause vibration or movement.

Let us know how you use Charlie's Bear!

Resources

» Charlie's Bear software — *CharlieBear.pde* from makeprojects.com/v/28
» RFID tag identifier — *RFIDread.pde* from makeprojects.com/v/28
» Arduino IDE — arduino.cc
» Audacity — audacity.sourceforge.net

1+2+3 Burnt Cookie Deflector

By Thomas R. Fox

You can make it!

YOU WILL NEED

Aluminum foil, heavy-duty
Cookie sheet roughly the same size as the cookie sheet you use to bake the cookies on

PROBABLY THE TOUGHEST PART OF baking great-tasting cookies is avoiding a hard, burnt bottom! While the problem could be that the oven's thermostat is inaccurate, the cause is more likely that infrared radiation is striking the bottom of the baking sheet, which heats it several hundred degrees hotter than the oven's air temperature. This really hot baking sheet is what burns the bottoms of the cookies.

To solve the problem, keep the baking sheet as cool as possible by using a radiation deflector shield, made by covering a second baking sheet with shiny aluminum foil.

1. Cut the foil.

Cut a length of foil 8" longer than the cookie sheet (or 2 lengths if your sheet is wider than the foil).

2. Cover the baking sheet.

Center the foil over the baking sheet, shiny side up, so you have 4" of overlap on each end, and secure it in place by folding the extra foil around the bottom of the sheet.

3. Set inside oven.

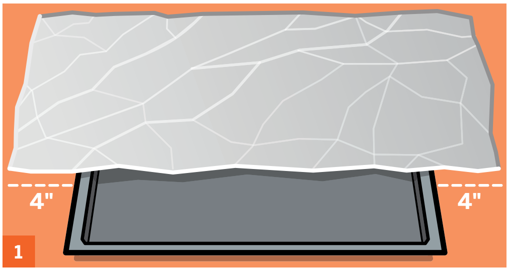
Place the oven rack for the cookies in the middle position of the oven, and move the deflector rack to the lowest position.

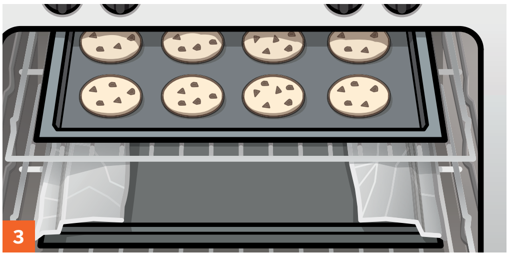
Invert the newly made deflector so the foil side faces down and the bottom of the cookie sheet faces up, and place it on the lowest rack.

Once the cookies are ready for the oven, simply place the baking sheet on the rack above the deflector. There's no need to adjust oven temperature or baking time.

Going Further

Visit makezine.com/28/123_burntcookie to learn more about the science behind infrared radiation and other ideas to minimize burnt-bottomed baked goods.





Damien Scogin; Tom Fox (photo)

Tom Fox (magiclandelectronics.com) is a book author and magazine editor.

BUILD NOTES

Wearable, wireless control network adds movement to musical performance.

Beatjazz Controller

BY ONYX ASHANTI

FOR AS LONG AS I CAN REMEMBER, I have wanted to make music when I dance, and even generate music *from* my dancing. From marching band performances to dance club sets, playing music and movement have always been inextricably linked for me.

As a saxophone and general woodwind player, I discovered the Yamaha WX7 MIDI wind controller in 1993, went electronic, and never looked back. Over years of busking, touring, and recording, I condensed my setup down to the controller and a laptop, and developed a methodology for live-looped, soft-synth-based improv that I call Beatjazz.

But I got tired of standing and pushing buttons. I knew that gestural sensors and wireless devices could let me create music freestyle, the way a beatboxer or breakdancer might do — to be a part *of* the party instead of just standing on the side playing *for* it.

I began experimenting with gestural control last year by strapping an iPhone running TouchOSC to my arm, and using it to send motion data to Pure Data (Pd) on my laptop. This whet my appetite, and so I decided to build the performance interface that I had always wanted.

Introducing the Beatjazz Controller, a wearable, wireless, 3-node network interface for live performance (Figure A, page 119). At its core, it's a MIDI wind controller that you wear, not hold. It lets you move your hands and head independently. But it uses standard woodwind fingering, so if you know how to play a sax, clarinet, flute, or recorder, you can play any digital synth and sound like or "be" anything.

In addition to its 8 regular finger sensors, the system has an accelerometer on each hand for gestural input, and 4-position "joy-toggle" mini joysticks at the index fingers and thumbs. The controls feed wirelessly into Pd running on a nearby laptop, and Pd translates their readings into MIDI notes, volume levels, and any other events and control parameters.

Pd lets you link the inputs to anything you want, so that, for example, you can change the sound you make by moving and tilting your hands in midair, and even switch the entire interface into a different mode by flicking a finger against a joystick.

To add more control options, the 8 regular finger buttons are force-sensing resistors (FSRs) that read variable pressure. Press one normally, and it keys just like a regular woodwind, but press it hard, and you can trigger any other action you assign in Pd.

Each network node (left hand, right hand, and mouth unit) has an Arduino microcontroller and an XBee wireless transceiver that communicates with corresponding modules on the base station laptop. I chose the Arduino Fio, which is designed for wireless applications. It's small and has a built-in "shoe" for plugging in an XBee. For its power (which also supplies the XBee), you connect its BAT pins to a 3.3V LiPo (lithium polymer) rechargeable battery, and you can charge it

TED/James Duncan Davidson

up by connecting 5V to the CHG pins.

The Fios and laptop all run Firmata, a system that lets Arduinos work as I/O devices for a base station computer. On the computer, Firmata converts all the signals it receives wirelessly from the Fios into OSC-formatted streams of numbers for output to Pd.

The Beatjazz Controller uses all open-source software and hardware. It works as one cohesive instrument, but every aspect of the design can be modified and shared.

Building the Beatjazz Controller

Program the XBees

First, install the FTDI drivers (at makeprojects.com/v/28) on your computer. This will let you program the XBee modules by plugging them into an XBee Explorer board and hooking the board up to your computer via USB.

I use faster 60mW XBee-Pros at the base station and the lower-power 1mW versions in the body units. Using Pro units all around would reduce latency at distances over 20–30 meters, I've found, but then the Arduino would have a hard time supplying the power. When I perform at normal distances from the computer, the 1mW body units and 60mW base units work well together.

To configure the XBees, I use Digi's X-CTU software — note that it's PC only. From X-CTU, update the firmware on each unit to the latest version, then download the config profiles from makeprojects.com/v/28 and load them to the units (Modem Configuration → Profile Load). Among other things, this will configure the body and base unit XBees to operate as pairs on 3 different channels.

Program and Test the Arduinos

The USB port on the Arduino Fio is only for charging batteries, not for programming. So to upload Firmata, you need to either connect it using an FTDI USB-to-serial (5 pin) adapter, or do it wirelessly via XBee. I chose the latter, following the directions at arduino.cc/en/Main/ArduinoBoardFioProgramming.

To test the computer connection, plug each body unit XBee into an Explorer board, then connect the board to a Fio using a mini USB cable. Plug your base station XBees into your computer, and their green communication lights should light up (Figure B). Note in your computer's System Properties which serial port the base stations are using, and also which physical USB ports they're plugged into (and use those same ports every time).

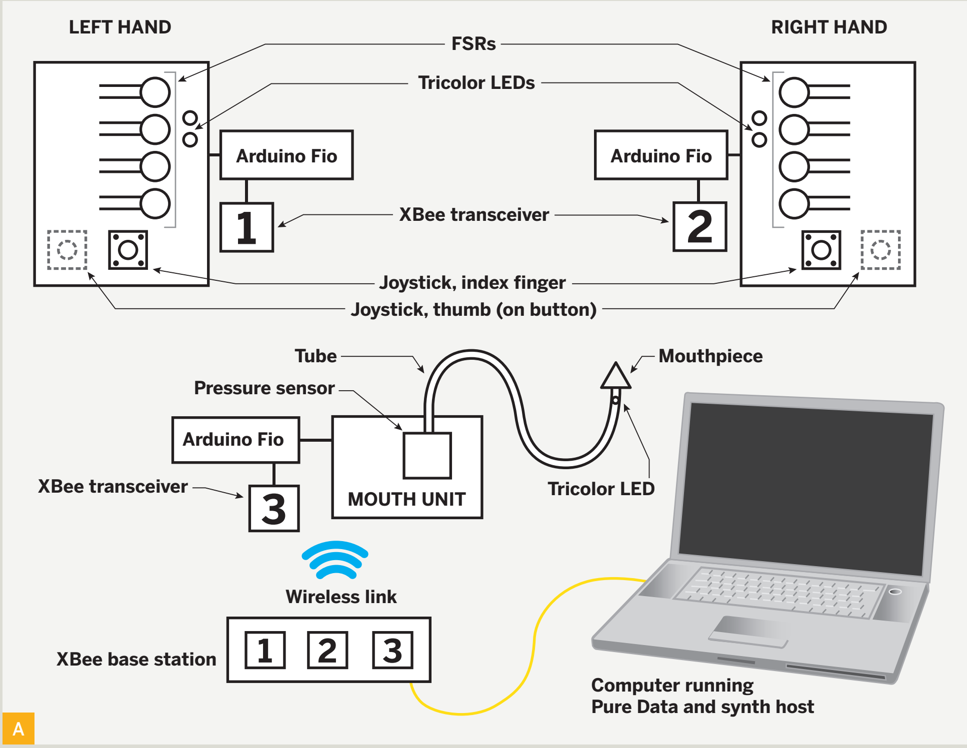
Download the Pd patch *arduino-test.pd*, open it in Pd, and click the base station's port on the "serial port #" array at upper left.

Hand Unit Electronics

The left and right hand control units are identical, so I'll just describe how to build one. The Fio has a narrower pin layout than a regular Arduino, so you can't plug in any of the standard prototyping shields. Instead, I soldered my own shields, which makes wiring (and rewiring) easier. The shields are just pieces of protoboard with 2 parallel 2×14-pin female headers spaced apart so their inner rows match the Fio's pins. Each contact is then jumpered out to its adjacent outer header (Figure C). Voilà: a Fio shield.

Connect 1×14-pin male headers to the back of the Fio, and plug them into the shield (Figure D, page 121). Then you can plug jumpers into the shield's outer header rows, and swap Fios without having to undo any wiring.

I mounted the joysticks with their resistors on their own mini protoboards (Figure E). This conserves space on the shield and makes it easy to mount the joysticks inside the hand unit cases. The FSRs (Figure F), accelerometer boards (Figure G), and tricolor LEDs all connect via jumpers to the shield. Note that the tricolor LEDs have 4 pins: R, G, B, and V+.



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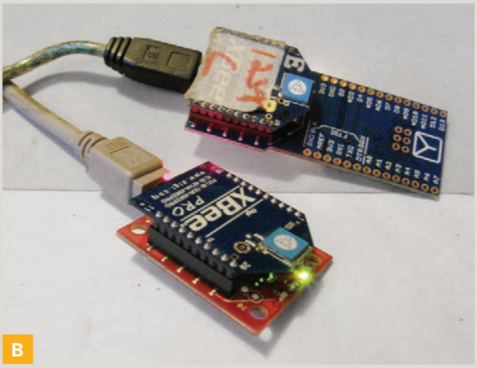
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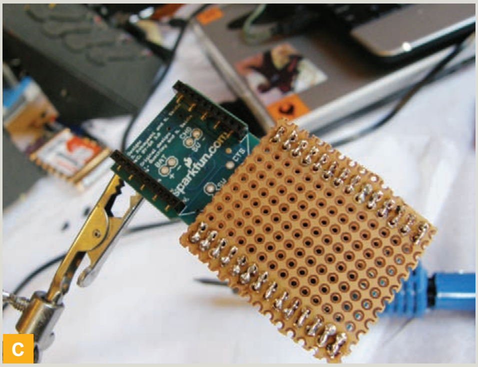
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MATERIALS

Arduino Fio microcontrollers (3)
XBee Explorer boards (3)
XBee-Pro 802.15.4 transceivers, 63mW (3) aka Series 1 Pro
XBee 802.15.4 transceivers, 1mW (3) aka Series 1
Batteries, 3.7V LiPo (3)
Resistors, 220kΩ or similar (40)
Accelerometer boards, 3-axis, MMA7260Q (2)
Force-sensing resistors (FSR), Interlink 402, 12.7mm (8)
Pressure sensor (gas), MPX5000
Joystick toggle switches (mini joysticks), 5-position (4)
Tricolor LEDs (5)
LED mounts (5)
Protoboard
Wire, 22–24 gauge stranded
Female pin headers, 2×14 (3)
Male breakaway pin headers, 1×40 (3)
Plastic tubing, 5mm, 3'
Guitar picks (2)
Buttons (for clothes), plastic (3)
Electric junction box, small
Thick cardboard, A4 size (2)
Nylon strapping, 3', with matching buckles (2) and tethers (2)
Bolts, 1" (8) with matching nuts
Washers (12) to fit bolts
Bottle caps (2)
Foam padding
Fishing line and zip ties

TOOLS

Soldering iron and solder
Glue gun and hot glue
Small drill or rotary tool
Hobby knife, super glue
Computer, Windows

Gerry Arrington (A); Onyx Ashanti

BUILD NOTES

Wearable, wireless control network adds movement to musical performance.

With everything plugged in, attach your battery to the Fio and turn it on. If the magic fried-electronics smoke doesn't escape, you're doing OK. Open the Beatjazz Controller patch in Pd, and enter the requisite port numbers for each unit in the "analog inputs" and "digital inputs" arrays. You should be able to jiggle the accelerometers and twiddle the FSRs and joysticks and see the numbers change on screen. If any input doesn't register, backtrack and see what's not working.

Mouth Unit

The mouth unit consists of a mouthpiece that connects via a plastic breath tube to a small control box that I hang around my neck. Inside the box are an air pressure sensor with a hose barb that takes the other end of the tube, plus an XBee, Fio, and supporting electronics — just like with the hand units. To furnish some bling, a tricolor LED sits on the tube in front of the mouthpiece, controlled by wires wound up from the box.

The mouthpiece lets me keep the tube in my mouth and articulate properly while I play. I designed a custom-print mouthpiece recently that I plan to make available for sale, but the first-generation mouthpiece described here is made by hot-gluing 2 guitar picks around the end of the breath tube.

As a woodwind player, you want your top teeth to rest about 4mm back from the leading (pointy) edge of the mouthpiece, with your bottom teeth just slightly in front of the edge, not resting on the bottom pick. This positioning helps you stabilize the mouthpiece and lets you to articulate the "Tu" sound that woodwind players use to "hit" their notes. After testing the mouthpiece in my mouth, I found the sweet spot. Then I cut a soft plastic button in half and super-glued the halves to the top and bottom picks to create anchors for my teeth to "lock" the mouthpiece in the right position (Figure H). I covered the anchors with more hot glue, then shaved it down until it was all smooth and comfortable in my mouth.

For the mouth unit controls and wireless, I used a small plastic junction box. I soldered a 5-pin female header to a small piece of protoboard, plugged in the pressure sensor, and connected the LED wires and necessary resistors on the board (Figure I).

Plug the breath tube into the pressure sensor (Figure J) and test the system the same way as the hand units: turn on the Arduino, open the Pd patch on your computer, and blow. The slider onscreen should move up and down with your breath pressure.

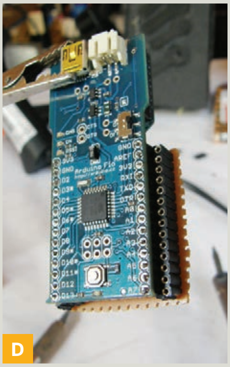
Before you cut the tube down to size, try wearing the mouth unit. Put the mouthpiece in your mouth, and turn your head in all directions. The tube should be just long enough to let you move your head freely.

For the final touch, insulate the LED's legs from each other, tape or zip-tie it to the tube (or any other location you see fit), and wire it along the tube to the box.

Hand Unit Cases

At this point you've assembled all the electronics, but your hand units are still 2 octopi of wiry wireless creatureness. It is time to give them exoskeletons. For my first hand unit experiments I tried PVC pipe, but that was too bulky, so I switched to strong cardboard. It's durable, cheap, and easy to work with, and if it tears, you just buy and cut some more. Once I converge on a design I like, I'll make a more durable version using carbon fiber.

To make the hand cases, print out the templates (available at makeprojects.com/v/28), transfer to poster board, and then cut and score where indicated with a sharp blade. Fold along the score marks, glue the side reinforcement flaps, fold the joint (Figure K), and let dry. Then glue the lid reinforcement. The case should now be very sturdy.



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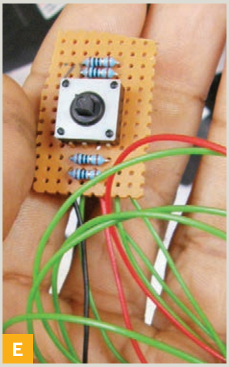

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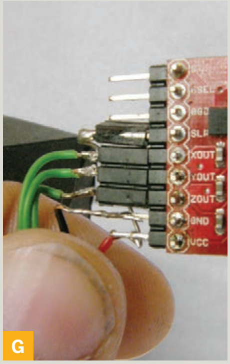

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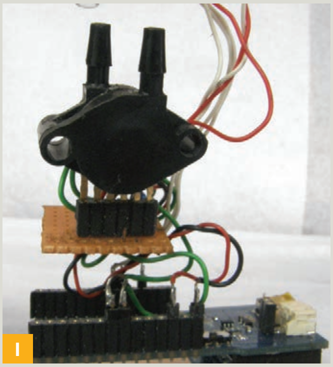

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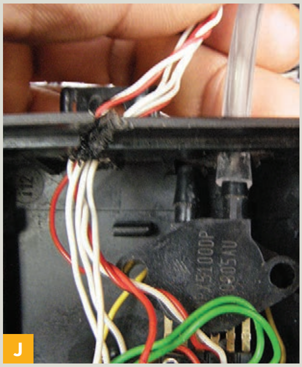

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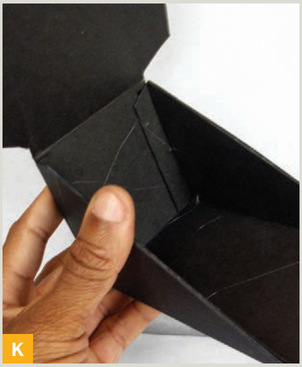

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Onyx Ashanti

For the straps, I used 10" lengths of nylon strapping bolted to the cardboard and fit with buckles. The end result is a 3-way harness with straps in front of the wrist, behind it, and through the case (Figures L and M).

Glue padding underneath the buckle, as it can become painful after a while. Try the boxes on, and hot-glue a bottle cap where your palm "dimples" in the middle; this will lock the controller in place (Figure N, page 123). Glue more padding along the edge where your palm touches the case just below your pinky and index fingers. This makes it easier to play notes that require no fingers or one finger.

Follow the case templates to mark and then drill or cut the holes for the FSRs, accelerometers, joysticks, and LEDs. Then mount the electronics.

I glued foam padding underneath each FSR to give them some spring action (Figure O). I also glued a button to the top of each lower joystick toggle switch, angled down so that I could flick it with a sideways twitch of my index finger without taking the finger off the

Wearable, wireless control network adds movement to musical performance.

key (Figure P). The accelerometer is mounted so that its x-axis runs left to right as you hold your hands palm down in front of you, the y-axis forward/back, and the z-axis up/down. Finally, I tied the battery down inside the case through small holes drilled in the back.

That's it — once these parts are all assembled (Figure Q), you should have a working Beatjazz Controller!

Time to Play!

In the Beatjazz Controller Pd sketch (Figure R), the FSR keys are numbered 1 through 4 for the left hand and 5 through 8 for the right, both running from index to pinky finger. Every control input should make something in the patch blink or move. Do a systems check: press the keys; move the joysticks in all directions; tilt and move your hands along each axis; blow into the mouthpiece lightly, then progressively harder, and back to lightly. The breath slider should mimic your expression. If it tops out or doesn't go its full range, calibrate it with a multiplier.

Now it's time to play some synths. Set Pd to transmit to the MIDI output. To connect it out to hardware, you can use a USB-to-MIDI dongle. But I do it all on the laptop, using FL Studio or Ableton Live for synth hosting and control (like looping), and a variety of synth plugins, including Native Instruments Kore 2, Minimonsta, and Drumaxx. To do this, use a virtual MIDI port like MIDI Yoke from MIDI-OX to route the output from Pd into your synth host. Select a synth, blow, and you should hear something. You're on your way!

Pd can assign control inputs to program changes as well as MIDI messages, which gives you super powers over changing modes mid-performance — kind of like immediately switching to a completely different instrument. In my example patch, for instance, the right upper joystick remaps the functions of both accelerometers. With so many possible control inputs, you won't run out of controller abilities anytime soon. The main challenge is developing sets of control function that work together symbiotically.

The Future

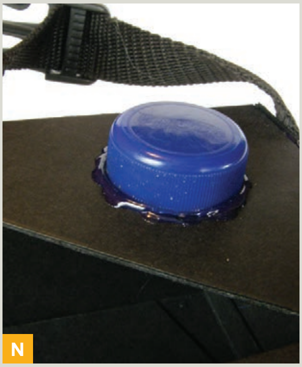
It took a lot of tinkering and a couple of blown Arduinos to get this first version to work. One design stretch is the breath pressure sensor; it's rated at 14.5psi, but humans blow most comfortably in the 1–2psi range. So I had to multiply the signal to death in the Pd patch, which makes it about one-third noise. For the next version I'll use a more suitable sensor.

I plan to incorporate gyroscopes and other sensors into later versions, but I have yet to max out the potential of the 2 accelerometers, so I want to do that first.

All along, my goal with this project was just to entertain myself. Performing for me was becoming more like a job — I was supposed to play covers, or my own stuff that people had heard before. Instead, I want to make people dance, move, or groove to what is going on at that exact moment, good or bad, to create a unique singularity of now. By creating sounds that respond to natural movement, you tell a story that can never be planned or repeated, and can only be fully appreciated by the people experiencing it in the same time and place.

I believe that everyone should be able to create and experience such stories, and I envision as many ways of creating Beatjazz as there are people. When this happens, there will be no performers and no audience, only creators connecting to each other. I offer the Beatjazz Controller as a step in this direction, and I hope that we get to play together some day. Live long and prosper.

Onyx Ashanti is a sci-fi-obsessed electronic jazz artist crossed with a futurologist instrument inventor, a virtuoso of wind instruments and improvisation who's determined to create the future of music.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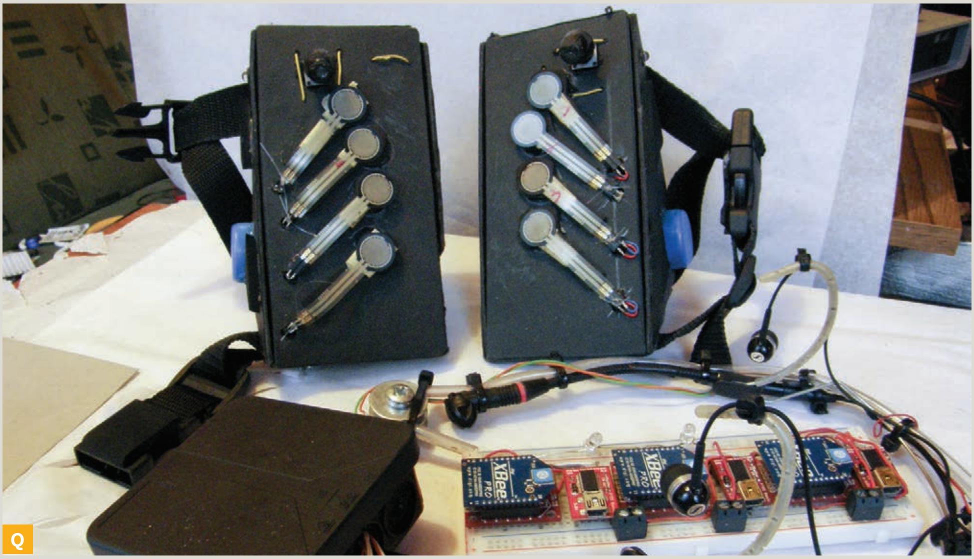

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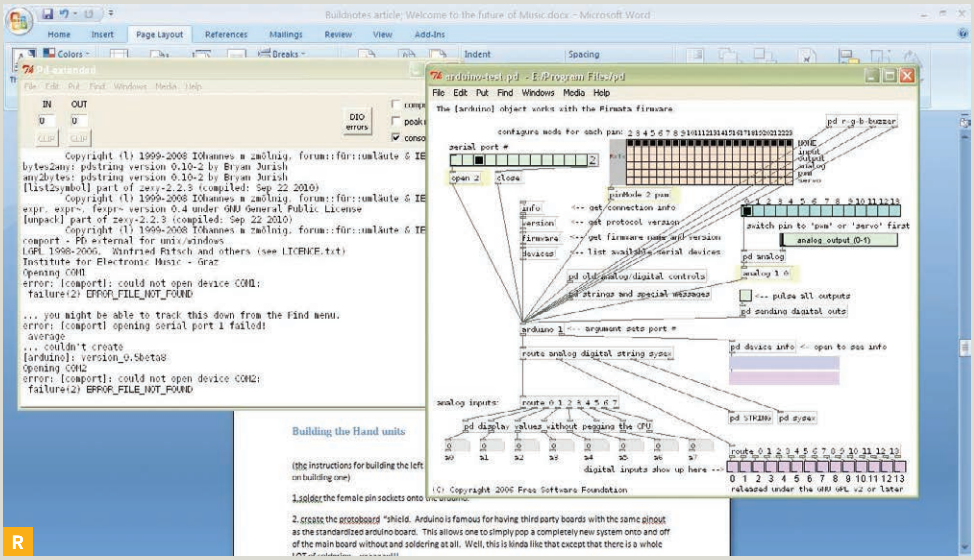

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Building the Hand units

R

Gregory Hayes

Simple Van de Graaff Generator

Shoot electrical sparks with a soda can, rubber band, and PVC pipe.

By Adam Wolf

WHEN I WAS YOUNGER, I SPENT HOURS perusing Bill Beaty's electrostatics web pages. At the time, I didn't achieve any real successes trying to build his high-voltage contraptions, and so my interest waned.

Years later, I saw someone online use a soda can as a collector for their Van de Graaff generator, and all my childhood memories of futzing with styrofoam and foil came rushing back. I made my first sparks that afternoon, after a quick stop at our local surplus store.

Here's the simple design I came up with after consulting several tutorials. Using this device, I've generated thick, bright sparks 3" long, and faint sparks 6" long. Hold your finger close to it in a darkened room and you'll see an eerie blue corona around your fingertip.

How It Works

There are 2 types of Van de Graaff generators. This one uses the *triboelectric effect*, in which certain materials become charged by contact with other materials — like when you rub a balloon with your hair.

During operation, a motor and roller at the bottom of the generator drive a rubber belt around a glass roller at the top, which creates a negative charge on the belt. A metal brush transfers this charge to a soda can, which is able to store a large amount of charge because it is both hollow and a conductor. The belt meanwhile becomes depleted of free electrons and needs to be replenished, and so a second brush at the bottom pulls in charge from whatever it's connected to.

1. Build the base.

Stand the 3"×1½" PVC coupling on its wide end, and insert the 1½"×1¼" bushing. Cut a length of 1¼" PVC pipe about 2" long and insert it into the bushing. Don't jam the parts together. Press-fit them just enough that they're joined, but loose enough to disassemble.

Connect the tee to the 2" length of pipe (Figure A).

2. Prepare the motor.

Wrap the motor in electrical tape so that it fits snugly inside the 1" side outlet of the tee.

To create the bottom roller, first wrap the motor shaft in tape until it reaches about ½" in diameter. Then split a length of electrical tape in half, lengthwise, and wrap the split tape around the middle of the roller (Figure B). This "crowned pulley" shape will help the rubber belt stay centered on the roller (*see MAKE Volume 22, "Puzzle of the Crowned Pulleys"*).

3. Make the collector.

After enjoying a 12oz aluminum can of your favorite beverage, rinse and dry the can. Remove the top with a can opener (Figure C). Be careful of the sharp edge inside.

4. Prepare the top roller.

To take the ends off a glass fuse, use a candle and 2 pliers. Grip one end of the fuse with one pair of pliers, holding its other end over the flame. Use the second pair of pliers to remove the hot end cap (Figure D), being careful not to touch the hot glass or solder. Repeat for the other end of the fuse.

Remove any wire inside the fuse with the pliers. If there's soot on the glass tube, clean it with rubbing alcohol and a cotton swab. From now on, try to keep the fuse dry and free of oils from your hand.

5. Make the top assembly.

The top assembly consists of a short length of PVC pipe underneath the can; inside the pipe is the glass top roller, mounted on a wooden dowel. The top brush enters through a hole across from the dowel, and its other

Adam Wolf

MATERIALS

PVC pipe coupling, 3"×1½"
These can be hard to find; you can substitute one 3"×2" and one 2"×1½".
PVC bushing, 1½"×1¼"
PVC coupling, 1¼"
PVC tee, 1¼"×1¼"×1"
PVC pipe, 1¼", about an 18" length
Electrical tape
DC motor, small, between 3V and 9V such as Jameco QJT-260-18130, jameco.com
9V battery snap connector such as Jameco 216452
4xAA battery pack with 9V connector snaps like Mouser 534-2476, mouser.com
Batteries, AA (4)
Wooden dowel, about ⅛" diameter or wooden/bamboo skewer
Glass fuse, about 1¼" long and ¼" in diameter
Large rubber band, at least ¼" wide, 12"–18" long
These are often found at office stores, meant to hold garbage bags in their cans.
Stranded wire, thick 14 gauge or 2.08 sq. mm works well.
Soda can, aluminum, 12oz

TOOLS

Knife or scissors
Can opener
Pliers (2)
Candle
Handsaw to cut PVC pipe
Drill and drill bits
Hot glue gun and glue
Wire strippers
Soldering iron and solder


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B

C


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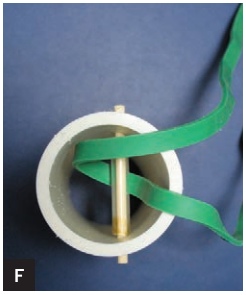
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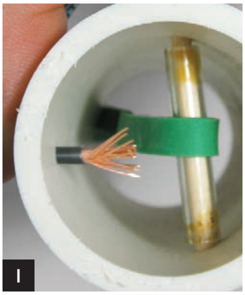
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end is connected to the can.

Cut a 5" length of PVC pipe, and push it into the 1¼" coupling. About ½" away from the coupling, drill a hole through the center of the pipe and through the other side. The holes need to be fairly level. With a hand drill, this may take more than one try. This pair of holes is for the dowel and the top roller.

Drill a third hole for the top brush. This hole needs to be large enough for the stranded wire, and located halfway between the 2 dowel holes, the same distance from the coupling (Figure E).

Cut the dowel to 1¾" long. Put the dowel through the first hole, the glass tube, the rubber band, and the second hole (Figure F). Use a little hot glue to secure the dowel to the PVC so it doesn't slip out.

6. Prepare the body tube.

The body tube is a single length of pipe that the rubber band runs through, between the top and bottom rollers.

To determine the right length for this tube, put the motor in the tee, loop the end of the rubber band over it, and hold the top assembly up. The belt needs to have a little tension, but too much tension just wastes power. Measure the distance between the top coupling and the top of the tee, and add 2" so the pipe is long enough to actually fit into the couplings. Cut the pipe to this length. You may need to shorten it later to adjust belt tension.

7. Add the brushes.

The brushes are made of stranded wire and are located next to each roller. The top brush connects to the collector. You hold the bottom brush while operating the machine.

You've already drilled one brush hole at the top. Drill a similar hole, on the opposite side, in the tee, large enough to fit the stranded wire.

Cut a 12" length of stranded wire. Strip 1" of insulation off one end and ¼" of insulation off the other end. Insert the end with ¼" stripped through the hole in the tee until it's about ½" from the bottom roller's surface (Figure G). Tape the wire down on the outside of the pipe with electrical tape (Figure H).

Cut an 8" length of stranded wire and strip 1½" of insulation off one end and ½" off the other. Insert the end with ½" stripped into the remaining hole in the top assembly so that the uninsulated wire is about ¼" from the rubber band, then tape the insulated section against the outside of the pipe to secure it. Untwist the stranded wire inside the tube and spread it out a little, being careful to keep it close to the rubber band but not touching (Figure I). Bend the other end of the wire over the top of the assembly and secure it with electrical tape (Figure J).

8. Assemble and adjust.

Insert the motor into the tee. Drop the rubber belt from the top assembly through the body.

Insert the body tube into the top assembly.

Use your finger to pull the rubber band down and loop it around the bottom roller. Carefully insert the body tube into the top of the tee, so that the brushes are on opposite sides.

Make sure the top and bottom rollers are aligned with each other. Hold the assembly up, look through the body, and check to see that the top and bottom brushes are close to the belt but not touching it. Also make sure the belt isn't twisted, or so loose that it hits itself.

9. Connect the motor.

Put the batteries in the battery pack, and snap the 9V connector onto the battery pack. Press each wire against one of the motor terminals. The motor should spin.

The brushes should point at the moving belt on the side where it exits (not enters) the rollers. If this is backward, swap the motor power wires. Unplug the battery pack, and solder the 9V connector's leads to the motor terminals. You can now use the battery snaps to connect and disconnect the motor.

Place the soda can on top so that the bare wire presses against it. Attach the battery pack. A charge should build up on the can!

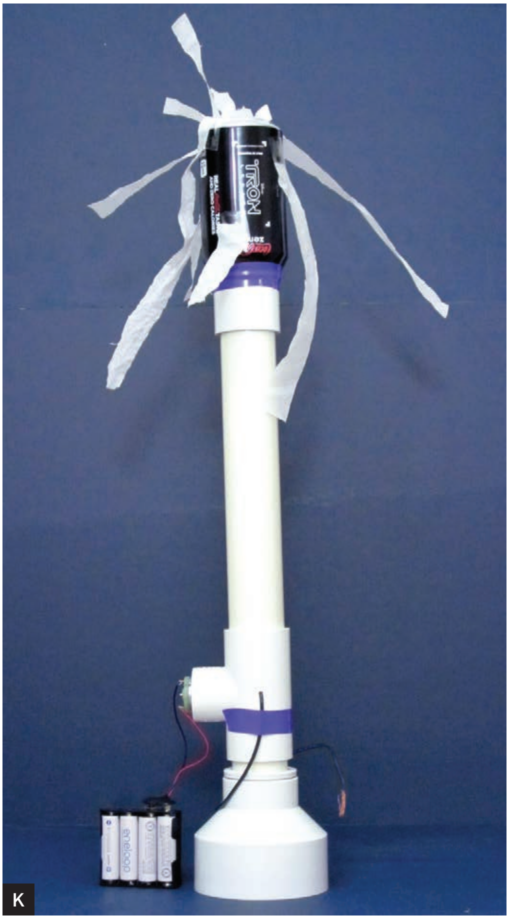
Operation and Experiments

To increase the stored charge, hold the bottom brush. You'll get the biggest sparks by holding the back of your hand flat alongside the can, and if you point a finger near it in the dark, you may see the air glow blue.

Tape threads or tissue paper strips to the can; they should spread out and repel each other (Figure K). Tape a bent paper clip or wire to the can, and instead of building up a charge, the end of the wire will create a small wind of ions. Blow bubbles or drop confetti near your generator and watch what happens.

Troubleshooting and Adjustments

Humid environments inhibit the triboelectric effect. Test-rub a balloon or a fleece blanket on your head; if it doesn't generate static, it's too humid. You may be able to get your Van de Graaff generator to work after blowing hot air through it with a hair dryer.



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If it still isn't working, remove the can and go back over Step 8 (assembly), checking the brushes and belt. Also try cleaning the rollers or replacing the rubber band. All working surfaces must be clean, dry, and free of oil.

Once the generator works well, cover the rim of the can with electrical tape and attach it to the coupling. Covering the can-opener marks increases the maximum charge.

Eventually, the Van de Graaff generator will attract dust, reducing its effectiveness. Wipe the dust off with a dry cloth to return the generator to peak ability.

+ For online resources, go to makeprojects.com/v/28.

Adam Wolf is a co-founder of Wayne and Layne, LLC, a company that makes open source hardware nerdery. He's a colorblind supertaster and lives in Minneapolis, Minn.

Watch Case Wrench

Make a custom tool in minutes to open your watch.

By Thomas J. Arey

MOST MAKERS DEVELOP A BUILT-IN sense of efficiency and economy that almost forces them to find better and less expensive ways of getting things done. This came through to me personally when my watch stopped running.

Given to me last holiday season by my loving wife, this watch has a battery-powered quartz movement. I assumed all I needed to do was pop the back off and make a quick battery change. But this was not to be the case.

Being water resistant, the watch has what's known in watchmaking circles as a Jaxa-type screw-on back, which requires a specialty wrench usually found only on a jeweler's workbench. Hmm!

As stated in the Owner's Manifesto (aka "Maker's Bill of Rights") first published in MAKE Volume 04:

» Cases shall be easy to open.
» Batteries shall be replaceable.
» Special tools are allowed only for darn good reasons.

In this case, perhaps a special tool was warranted, but I wasn't happy. As Mister Jalopy tells us: "If you can't open it, you don't own it!"

A quick trip around the web pointed me to a number of sources where I could purchase the required wrench, but the shipping and handling costs frequently exceeded the tool cost. Spending $15 or more to replace a $2 watch battery just did not sit well with this maker. Time to head to my workbench!

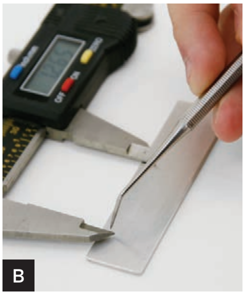
The basic physics involved here applies to any wrench-type tool. You need a certain amount of torque to overcome the friction of the screw threads and twist open the watch

Sam Murphy

MATERIALS AND TOOLS

Aluminum bar or sheet stock, ¾"×1/16" thick or similar. A scrap about 4" long is all you'll need.
Calipers or finely calibrated ruler
Marker pen or metal scribe
Hacksaw or other small handsaw
Pliers
File


A


B


C


D


E


F

back. How to do this without needing to buy a special tool?

1. Measure the watch back's slots.

My first attempts at using various standard tools to open the watch merely scratched it. I can only assume a Rolex owner might get surly at this, hence the "professional" tool. So I set about measuring the slots on the watch back (Figure A), and the little maker LED in my head lit up.

2. Mark and cut the metal stock.

From my scrap metal pile, I took a short piece of aluminum stock ¾" wide and 1/16" thick. The thickness was close enough to the slot width on the watch cover that no further filing was required there.

It was a simple matter to cut out a section corresponding to the slot distance (Figures B and C). I folded the cut-out section over, to give the wrench added strength; you can also cut or break the section off entirely for additional clearance, as shown here.

3. File it smooth.

A bit of filing and grinding cleaned up any sharp edges that might create scratches and dings on the watch back's surface (Figure D).

4. Open the watch.

The back was off with a quick twist (Figures E and F) and I was off to the store to buy the replacement battery.

So now I have a custom wrench to take care of any future battery replacement needs for this particular watch. Total time expended, about 15 minutes. Total cost, zero. Even if you bought new aluminum stock at your local home center or hardware store, your cost would still be significantly less than ordering the "proper" tool online.

You could probably use almost any metal stock to make the wrench. For my watch, aluminum was sturdy enough to perform the task; a tighter watch back might require using steel. Experiment!

Being able to take care of your own devices is what being a maker is all about. Doing it with tools of your own design and construction is even more fun.

T.J. "Skip" Arey has been a freelance writer to the radio/electronics hobby world for over 25 years and is the author of *Radio Monitoring: A How To Guide*.

Copper Tool Tidy

Build a desktop stand for your essential small tools.

By Andrew Lewis

A TOOL TIDY IS A GREAT PROJECT TO FILL up a quiet autumn afternoon. I remember my woodworking teacher setting the task of making a workbench organizer. I was about 10 years old and thrilled at the thought of using real wood and proper workshop tools.

Fast forward 20 or so years, and I find myself sitting at my own workbench with a pile of screwdriver tips, picks, pincers, and assorted small tools in need of a home. It's time to revisit my school days and make an improved version of the organizer that taught me how to use workshop tools.

1. Cut the copper pipe to size.

Cut the 30" length of copper pipe into the following sizes and quantities: 6" (1), 5" (2), 4" (2), 3" (2).

2. Prepare and cut the wood block.

Cut your wood block to the desired size. Mark a ½" border on the top surface. This border will help keep the block looking neat and serve as a guide for marking out the holes you'll drill.

You'll be drilling holes across the back of the block to accept the ¾" copper pipe, so mark a line horizontally across the block ⅜" (half the diameter of the pipe) in from the border you drew previously.

Mark the center of the horizontal line where the 6" piece of pipe will be positioned. I used a 9" block, so the center of my line was 4½" in from the edge of the block.

Divide up the space on the line for the remaining copper tubes. I spaced the tubes equally, although they can be offset if you prefer. Just remember that the edge of the copper tube should stay inside the ½" border.

Andrew Lewis

MATERIALS

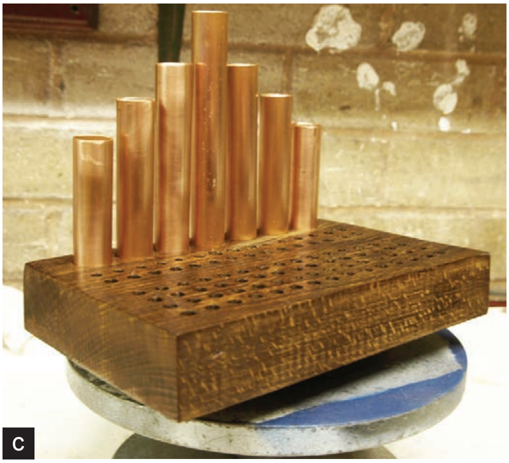
Wood block I used a 9"×6"×1½" beech block
Copper pipe, ¾" diameter, 30" length
PVA glue aka white glue
Wood polish or varnish
Wood stain (optional)

TOOLS

Hacksaw or copper tubing cutter
Pencil and ruler
Drill
¾" spade or Forstner bit
3mm drill bit for pilot holes
7.5mm drill bit for screwdriver tips
9mm or other size drill bits (optional)
Sanding block or electric sander


A


B


C

3. Mark and drill the tool holes.

The front of the block will be used to hold screwdriver tips, so mark out a ½" grid inside the border. The intersection points of the grid lines will guide where to drill your holes.

If you want to drill larger or smaller holes to accommodate specific tools, be sure to mark this clearly on your grid. I opted to make the rear row of holes 9mm wide and to leave out a row in the middle. The missing row makes a handy place to rest a pencil and gives larger tools a little breathing room (Figure A).

Use a small drill bit, such as 3mm, to drill pilot holes, then step up to the larger bits; 7.5mm works great for screwdriver tips. Try to get the holes for the driver bits about ½" deep. If you don't have a pillar drill (drill press) with a depth stop, wrap a piece of masking tape around the drill bit to set the depth.

The holes for the copper pipe can be a little deeper, but try not to drill all the way through the block by accident. The spiked point of a spade bit can be deceptively long.

4. Sand, glue, and finish.

Sand the wood block smooth and apply wood stain if desired (Figure B). Add a little PVA glue to the ¾" holes, and push the copper tubes into place. Finish with polish or clear varnish (Figure C).

Andrew Lewis is a keen artificer and computer scientist with interests in 3D scanning, computational theory, algorithmics, and electronics. He is a relentless tinkerer, whose love of science and technology is second only to his love of all things steampunk.

Thomas R. Fox

Plant Light Stand

Shed some light on a growing problem.

By Thomas R. Fox

IF YOU AREN'T FORTUNATE ENOUGH TO have a heated greenhouse but still want to start your own plants from seed in the winter, this inexpensive plant light stand will get your plants growing — even in a dark, dungeon-like basement. It's made primarily from common 2×4 boards, ⅜" plywood, and fluorescent shop lights.

A neat feature of this stand is the adjustable height of the lights over the plants. You can easily raise the lights as the plants grow, which keeps the leaves from burning and gives the plants plenty of light for good, healthy growth.

This free-standing, 4-shelf plant light stand can hold as many as 8 shop lights and 16 standard-sized 10"×20" plant flats. If you don't need that much space for growing plants, you can start out with just 2 shop lights over one shelf and easily expand it in the future if you want to grow more. In the meantime, you can store your growing supplies on the unused shelves.

1. Mark the legs.

Mark the 66" 2×4 legs where you'll attach the shelf supports, following Figures A and B. You can download the full-sized drawings at makeprojects.com/v/28.

Note that the shop lights, shop light supports, and power strips are not shown in Figures A and B; you'll install them later, after you've built the shelving.

2. Cut some corners.

Make the special cuts required on the ends of the eight 21" side shelf supports to make simple corner laps with the legs, as shown in Figures C and D.

MATERIALS

2×4 dimensional lumber, cut to lengths of 66" (4), 50" (8), and 21" (12)
2×2 dimensional lumber, cut to lengths of 72" (8) and 62" (8)
⅜" exterior plywood, 4'×8' sheet cut into 4 shelves, 2'×4'
Bolts, ¼"×6" (16)
Deck screws: #10×3" and #8×1½"
Washers to fit #8 screws
Shop lights, 48", 2-lamp, 32W–40W fluorescent, cool white, warm white, or wide-spectrum (2–8) Use 8 shop lights (2 per shelf) for maximum growing area. You can start with just 2 shop lights and expand later.
Power strips (1–2) at least one for every 4 shop lights

TOOLS

Saw(s) to cut lumber and plywood
Drill with ⅜" bit
Screwdrivers or driver bits to match your deck screws
Pliers, long-nose or needlenose

3. Attach the shelf supports.

Use 3" #10 deck screws to fasten the 50" front and back shelf supports and 21" side shelf supports to the legs (Figures E and F, following page). Start at the bottom and proceed upward. It's easiest if you have a helper when you attach the bottom shelf supports to the legs.

Use 3" #10 deck screws to attach the four 21" center shelf supports to the front and back shelf supports (Figure G).

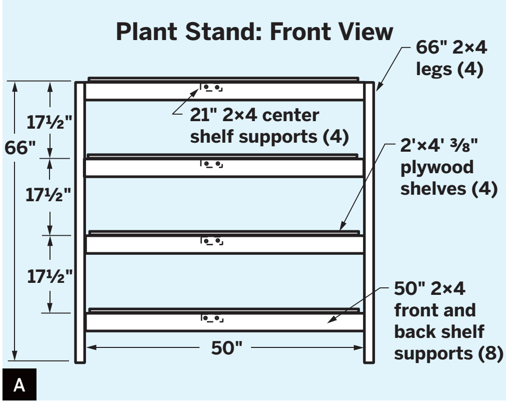
4. Add the shelves.

Use 1½" #8 deck screws to fasten the 2'×4' ⅜" plywood shelves to the shelf supports (Figure H). This completes the shelving.

5. Make the adjustable light supports.

Next, you'll add shop light supports to the shelving. These adjustable supports consist of 2×2 boards with ⅜" holes drilled 1" apart. Then 6"-long ¼" bolts are placed through the holes (Figure I). This arrangement makes it quick and simple to raise or lower the shop lights in 1" increments.

Marking all holes first, start 9" from the end of a 72" 2×2 board, and drill ten ⅜" holes



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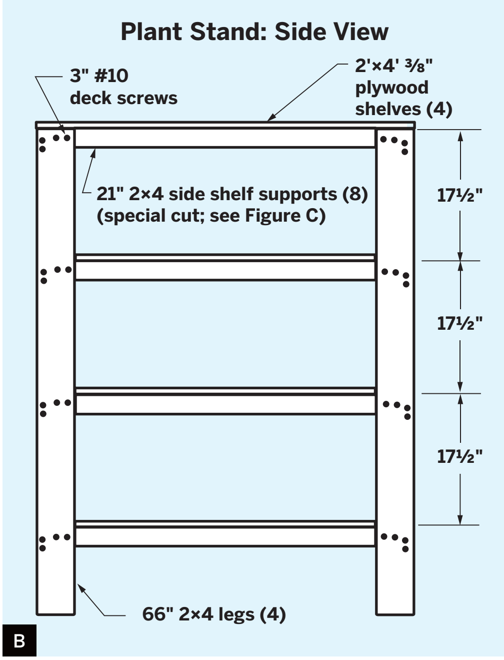

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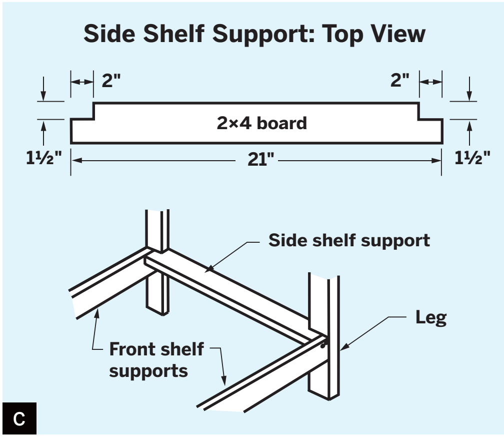


C

spaced 1" apart. Then 10" from the last hole of this group, drill 10 more holes, each 1" apart. Repeat this process until you have 40 holes in 4 groups, with a 10" space between each group. Using the first drilled light support as a guide, mark and drill the same 40 holes in each of the other seven 6' 2×2s.

6. Attach the adjustable light supports.

Mount the adjustable light supports vertically to the sides of the stand using 3" #10 deck screws. Each pair of companion supports should be spaced about 1¾" apart so that a 2×2 board can slide between them (Figure J). The outside light support on each side should snug up next to the adjacent leg and line up with the bottom edge of the lowest shelf support (Figure K). The 6"-long ¼" bolts will be placed through the holes in these supports (Figure L), so make sure all the holes are lined up and oriented as shown in the photos.

7. Mount the lights.

Remove the 2 S-hooks from the box that the shop light came in, and place the shop light (without bulbs) on one side of a shelf. Slide a 62" 2×2 board between both pairs of adjustable light supports and let it rest on top of the shop light.

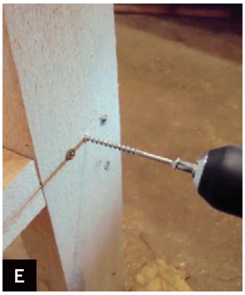
Insert one end of each S-hook into the small holes on top of the shop light, and use long-nose or needlenose pliers to squeeze the hook so it won't slip out of the holes. Then (adjusting the position of the light as necessary) attach the other end of each S-hook to the 2×2 with washers and a 1½" #8 deck screw (Figure M).

After attaching your lights to the 2×2s, slide each assembly up through the light supports to the desired height and hold it in place with the bolts.

8. Use your light stand.

Mount the power strips and plug in the shop lights (Figure N). If you're using more than 4 shop lights, it's a good idea to use at least 2 power strips. Keep in mind that nearly 7 amps of current are being used when all 8 shop


D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lights are on at the same time, and that most household circuits are designed for a maximum of 15 amps.

Standard residential or utility-type 32W–40W fluorescent lamps can be used. However, for best plant growth, you'll want to use wide-spectrum fluorescent lamps, such as Gro-Lux or Vita-Lite. A slightly cheaper alternative, which will provide light nearly as good as wide-spectrum bulbs, is to use one cool white and one warm white bulb in the same shop light.

Tips on Starting Plants from Seed

Many seeds, such as tomato, pepper, zinnia, and marigold, germinate much more quickly and reliably when the soil temperature is above 70°F. If you use your plant light stand in a cool basement that averages below 55°F, it's best to use soil heating cables to help with germination.

However, in a relatively warm basement — one that averages above 55°F — you can reliably grow warmth-loving plants by simply using the radiant heat energy from the shop lights' fluorescent lamps.

To maximize the heating effect, adjust the shop lights so the fluorescent bulbs come within 1"–2" of the soil. Also, leave the shop lights on day and night until most of the seeds germinate. I found from experience that this method works, and it practically eliminates the dreaded "damping-off" diseases that kill seedlings, as long as you use high-quality, professional-grade potting soil.

This method also works fine for starting cool-weather-loving plants such as onions, cabbage, broccoli, impatiens, and poppies. But since these germinate well at relatively low temperatures, you don't need to leave the shop lights on continuously — usually 12–15 hours per day is sufficient.


J


K

TIP: **Before mounting each companion support to the shelving, put a bolt through a hole in the first support and line it up with the corresponding hole in its companion.**


L


M


N

Tom Fox (tomfox@magiclandfarms.com) is an Michigan-based electronics/science/weather geek, technical writer, workshop editor, handyman, dirt farmer, and more. His wife and children's favorite title for him is "repairman."

Solar Wax Melter

Purify beeswax with a simple sun-powered oven.

By Abe Connally and Josie Moores

ONE OF THE BONUSES OF KEEPING A TOP bar beehive, like the Honey Cow (*see MAKE Volume 25, page 123*), is the production of beeswax. Wax can be used for a variety of things, like homemade remedies and salves, bee lure (*Volume 27, page 132*), creative candles, or sculptures.

Most people melt beeswax in a double boiler, which is a container of wax within a container of water. You simply heat the water container, and the wax melts. But that approach uses valuable energy and time.

Our solar wax melter is basically a simple solar oven. It consists of an outer box, insulation, an inner heat chamber, a wax screen, a wax container, and a clear top. The raw comb is placed on a screen, and as the sun heats the oven, the wax slowly drips through the screen into the container below. You're left with a nice chunk of screened wax.

By creating a solar wax melter, you can save all that wonderful beeswax, energy, and time by just dropping in your chunks of comb and letting the sun do the hard work!

1. Plan your measurements.

1a. Measure your pan. This will determine the dimensions of the entire box. The aluminum pan we use is 17"×12"×3".

1b. Your inner box will be 1" larger on all sides than your pan, in our case 19"×14". Because we use 1×8 lumber for the outer box, and we have 1" of insulation below the inner box, the inner box height will be 7".

1c. Plan for your outer box to be 3" larger on both sides than the pan (1" for inner box

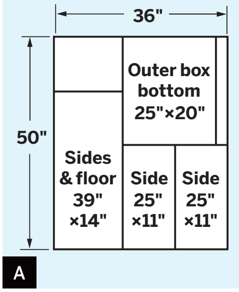
Abe Connally and Josie Moores

MATERIALS

Pan to catch molten wax. We use a cheap 17"×12"×3" aluminum roasting pan but you can use almost anything. Metal is preferable, and try to keep it 3" deep or less.
Dimensional lumber, 8' lengths, one each of: 1×1, 1×2, 1×8
Sheet metal, 50"×36"
Shade cloth or screen, 19"×14"
Drywall screws or #8 wood screws: 1½" and ¾" or whatever you have on hand that will work
Sheet metal screws, self tapping, ¾"
Transparent plastic film, 27"×24" Sold as greenhouse plastic, this is typically 3mil or 6mil polyethylene film. Rigid clear plastic will also work but is more expensive.
Perlite or other lightweight insulation material such as vermiculite, sawdust, rice hulls, wood ash, or shredded paper
Staples
Silicone sealant
Black paint

TOOLS

Cordless drill and ¼" bit
Circular saw
Tinsnips
Scissors
Tape measure
Straightedge
Pen, pencil, or other marker
Hammer
Paintbrush
Staple gun



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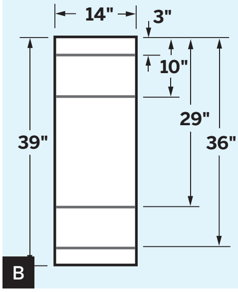

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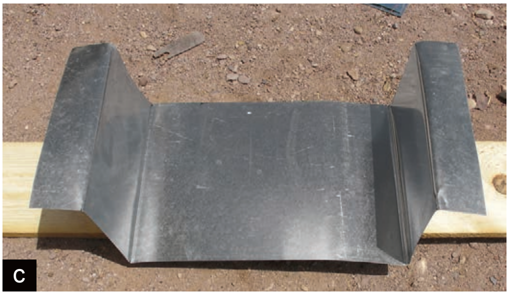

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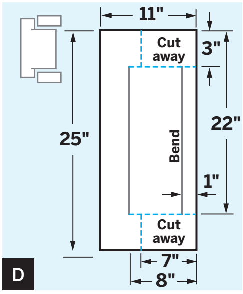

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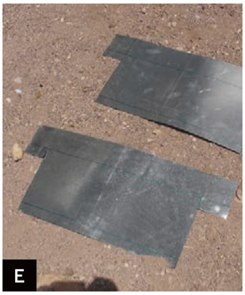

E

thickness + 2" of insulation). The inside dimensions of our outer box measure 23"×18"×8". You can adjust your dimensions according to materials on hand.

2. Build the inner heat chamber.

2a. Using tinsnips, carefully cut the 4 pieces of sheet metal according to the diagram in Figure A: one piece 14"×39", 2 pieces 11"×25", and one piece 20"×25".

2b. Bend the 14"×39" piece according to the diagram in Figure B: at 3" bend away from you, at 10" bend toward you, at 29" toward you, and at 36" away from you. You're creating a U shape with 3" wings, which constitutes 2 sides and the floor of the inner box (Figure C).

2c. With an 11"×25" piece oriented vertically, as shown in Figure D, measure in from the right side and mark both 11" edges at 1", 7", and 8". Draw vertical lines between these marks. Mark the righthand 25" side at 3" and 22", and make corresponding marks on the vertical 8" line, then draw lines between these marks horizontally.

2d. Cut from the right along the horizontal lines at 3" and 22" until they meet the line at 8". Now cut from the 11" edges along the 7" line until you reach the slices you just cut. Don't discard these scrap pieces — you'll use them later. You now have a T-shaped piece with small tabs. Repeat this procedure to cut the second 11"×25" piece of sheet metal (Figure E).

2e. On each 11"×25" piece, bend (toward you) along the 1" line. Flip over, and bend (toward you) along the 8" line, leaving the small tabs straight. You now have the inner box's remaining sides (Figure F).

2f. Bend the scrap pieces from Step 2d in half lengthwise to form 4 corner pieces (Figure G).

2g. Place one side piece with its 1" folded length under the long bottom edge of the U-shaped floor piece. Use 4 self-tapping sheet metal screws to attach the 2 pieces together, screwing through the floor into the 1" folded edge of the side piece. Repeat for the remaining side piece. You now have a basic box with large tabs around the top (Figure H).

2h. Line up the corner pieces from Step 2f on each outside box corner, and screw them on from the inside out. Be careful to avoid getting nicked by protruding screws. Use 4 screws for each corner piece (Figure I).

2i. Apply 2 coats of black paint to the inside of the inner box only (Figure J). Do not paint the upper tabs.

3. Build the outer box.

3a. Mark the 1×8 board at 23", 46", 66", and 86". Using a circular saw, cut the board at these marks to make 2 boards 23" long and 2 boards 20" long.

3b. Use the ¼" drill bit to make 2 holes at each end of the 20" boards, ½" from the edge. These are clearance holes for your wood screws; they allow the threads to pass through but stop the head from passing.

3c. Find a flat surface, and set up all 4 boards to form a box, with the 23" boards inside the 20" boards. Screw the box together with 1½" wood screws, through the clearance holes you drilled (Figure K).

3d. Mark the halfway point on both 23" boards, near the bottom edge of the box. Drill a clearance hole at each halfway point,


F


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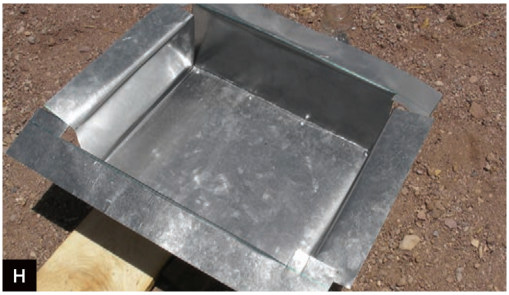
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½" from the bottom edge. Cut an 18" length of 1×1 and insert it between the 23" boards at the halfway point. Make sure this board is flush with the bottom of the box, then screw it in place using 1½" wood screws (Figure L). We used a couple of extra 1×1s at either end because we cut our bottom too short (see the next step), but you won't need these.

3e. Next attach the bottom. Using ¾" wood screws, attach the 20"×25" metal sheet to the outer box frame and to the middle support board as additional reinforcement. Place a screw every 4" or so around the perimeter and along the center support (Figures M and N).

4. Insulate and seal.

4a. Place a layer of insulation in the bottom of the box. We use perlite, but any loose fill material should work well. Sawdust, rice hulls, vermiculite, shredded paper, and wood ash are good candidates. Fill to the top of the 1×1 bottom support board (Figure O).

4b. Place the inner box into the outer box, centered so there's a 2" gap on all sides. Fill this gap slowly with insulation. Bend the metal tabs upward a bit to allow for access to the gap. Fill in a little at a time on all sides so the inner box stays centered and the gap fills at the same rate. Periodically, stop filling and gently pack the insulation into the space. Continue filling all the way to the top.

4c. Using ¾" wood screws, attach the metal tabs of the inner box to the top of the outer box. Start at one corner and work your way around. Note that the small tabs of the inner box should lie beneath the wings of the floor piece. Go around the edges with a hammer and bend the metal down to avoid any sharp, dangerous protrusions (Figure P).

Seal all cracks and seams with silicone.

5. Make the wax screen.

5a. Cut two 17" lengths and two 10" lengths of 1×1 lumber. Drill a clearance hole through each end of the 17" pieces, ½" from the edge.


L


M


N


O


P

Lay out the rectangle on a flat surface so that the 10" pieces lie inside the 17" pieces. Screw the frame together with 1½" screws.

5b. Center the shade cloth over the frame, and staple one edge of the cloth to one side of the frame. Pull it tight, and staple the opposite side. Staple around the perimeter, pulling it tight as you go (Figure Q, following page).

6. Make the lid.

6a. Cut two 25" lengths and two 22" lengths of 1×2 lumber. Drill 2 clearance holes on each end of the 22" pieces, ½" from the edge. Lay out the rectangle on a flat surface, so that the 25" pieces lie inside the 22" pieces. Screw the frame together with 1½" screws.

6b. Cut a section of greenhouse plastic, 27"×24". Center this over your rectangle, and staple one edge to one side of the frame. Staple around the perimeter of the frame, carefully pulling the plastic tight (Figure R).

7. Melt some beeswax.

The solar wax melter is easy to use. In the morning on a bright, sunny day, drop your pan into the inner box, put the screen over it, and place a few chunks of comb on the screen (Figures S and T). Place the lid on top and use a few small stones to help hold the plastic film against the rim of the inner box, making a good seal (Figure U). The box should attain temperatures of 200°F or more.

Adjust the orientation of the box throughout the day so it tracks the sun. The wax should melt fastest between 10 a.m. and 2 p.m. We're able to melt a full comb in about 10 minutes during the hottest hours of the day.

When the wax has melted, remove the pan, let it cool, and pop out your chunk of wax. Or you can continue to add comb to build up a larger chunk of wax for storage or projects.

The wax melter can also be used as a solar oven for cooking small meals or pasteurizing water when you're not melting wax.

Online Resources

» Tools, accessories, and DIY kits for top bar hives: goldstarhoneybees.com
» Natural beekeeping forum: biobees.com
» Authors' site: velacreations.com/bees.html

Abe Connally and Josie Moores are an adventurous couple living in an off-grid hideaway with their two boys. Their experiments with energy, architecture, and sustainable systems are documented at velacreations.com.


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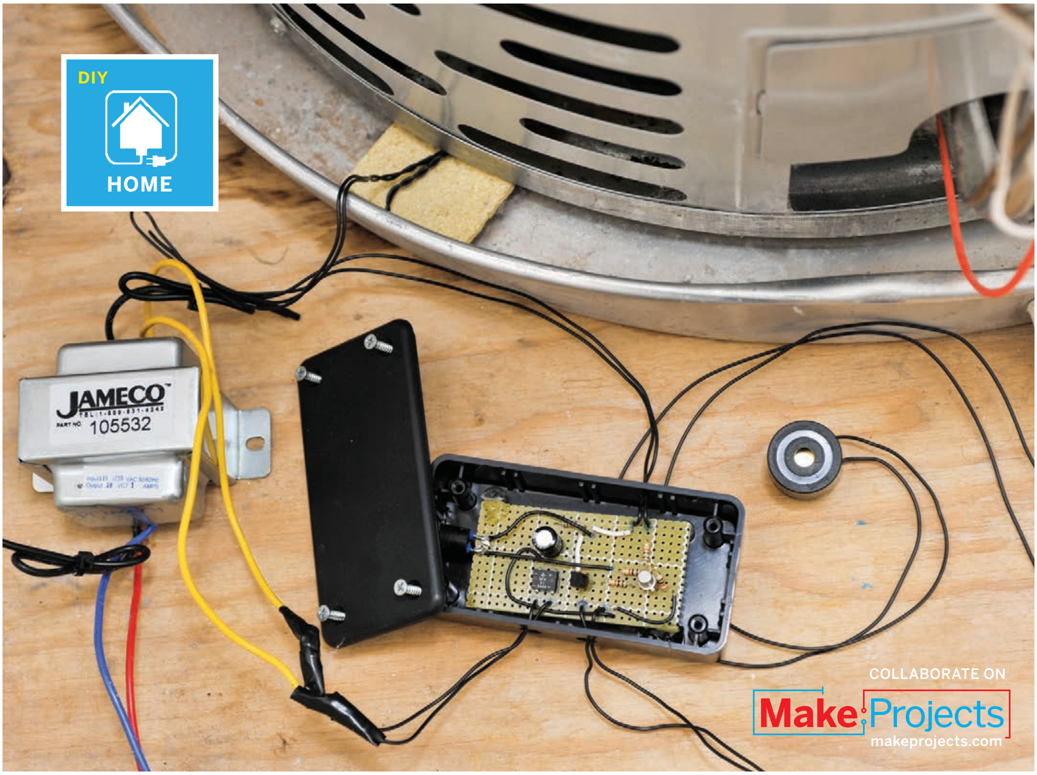


Water Leak Detector

This simple circuit saved the day when an attic water heater failed.

By Jeff Tregre

THE AVERAGE LIFE EXPECTANCY OF A hot water heater is about 10 years, so it's not a question of *if* it will leak — it's simply a matter of when. In my part of the country, homebuilders have been installing these tanks in the attic. This saves space, but also means that if you don't go upstairs very often, you may not realize that your heater is leaking until it has caused hundreds of dollars of damage to your ceilings and walls. Yes, new building codes mandate a drain pan, but these can clog or corrode.

I realized that my two water heaters were 10 years old and started researching water leak detection systems. I soon realized that I could make a system that would work just as well for much less money. Here's a leak detector circuit I designed that costs less than $25 and draws power from my doorbell transformer. This works nicely because the transformer is already installed in the attic and it's on 24/7. You can also use a dedicated transformer.

Does this leak detector work? The answer is a big yes. Just a few weeks after I installed it, I came home from work and heard it buzzing. Upon investigation, I discovered that my primary water heater was leaking, and that its drain pan was clogged and already half full. My little circuit had saved the day.

Build the Circuit

Figure A (following page) shows a schematic for the water leak detector circuit. Start by

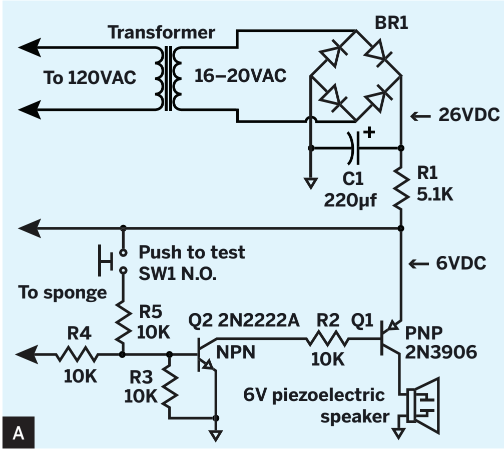
Gregory Hayes

MATERIALS

Bridge rectifier, at least 50V, 1A
Capacitor, electrolytic, 220µF, 35V
Transistor, PNP, 2N3906
Transistor, NPN, 2N2222A
Resistors, ¼ watt: 5.1kΩ (1), 10kΩ (3)
Piezoelectric buzzer, 6V
Switch, SPST pushbutton, normally open (N.O.), panel-mount
Wire, insulated, 18–22 gauge stranded, multiple colors
Wire, solid copper, insulated, 18–20 gauge
Project box, small
Perf board, 2" square
Machine screws, about 1", with matching washers and nuts (2)
Wood screws (2)
Kitchen sponges, pop-up, 3"×4"
Transformer, 16V–20V AC step-down You can use your home's existing doorbell transformer.

TOOLS

Soldering equipment and solder
Drill and drill bits, sized to screws
Needle, large
Scissors



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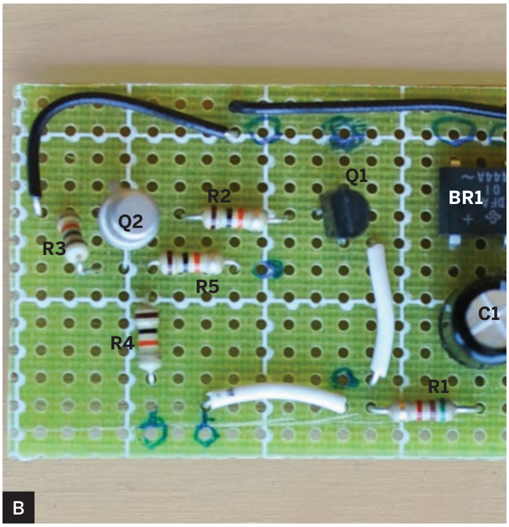

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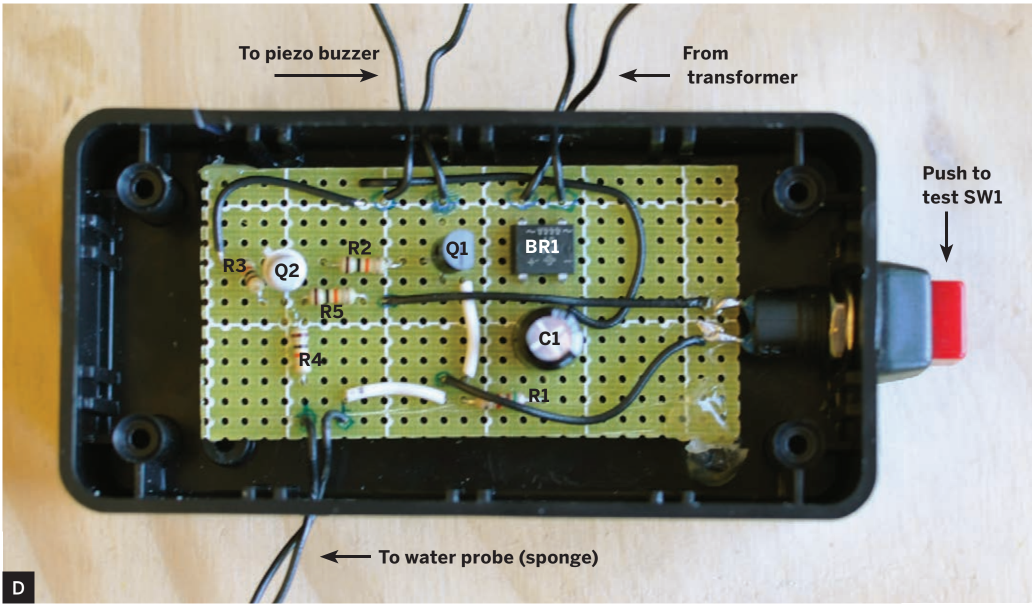
C

soldering 2 wires into a bridge rectifier and then a filtering electrolytic capacitor on a small perf board. This will convert the AC from the transformer to DC with a ripple waveform, with voltage following the formula *VAC* × 1.414 = *VDC (RMS)*, or about 23V–26V DC.

Continue building the circuit on the board (Figure B), following the schematic. A 5.1kΩ resistor inline (R1) reduces the 23V–26V AC to 6V, which drives a 6V piezoelectric buzzer when either the push-to-test switch is pressed or water is detected.

Drill a hole in one side of the project box for mounting the pushbutton switch (Figure C), and smaller holes in back for mounting the board inside with machine screws. Drill small exit holes for the wires leading to the transformer, the buzzer, and the water probe.

Disconnect the power to your transformer, then connect the 2 wires from the rectifier to the transformer's secondary side. Finally, connect the piezo buzzer using wires long enough to reach just outside your attic door, or another location where its sound won't be blocked from the rest of the house.



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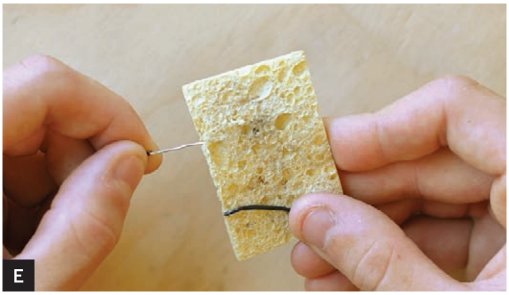
Install the Water Probe

Use a large needle to pierce 2 parallel holes into the side of a sponge, about 2" deep and 1" apart. Strip at least 2" of insulation off 2 pieces of solid copper wire, and insert the bare copper into these holes (Figure E). Wrap the rest of the wire snugly around the sponge so that the bare copper ends will not come out (Figure F).

Connect the other ends of the copper wires to the circuit, and lay the sponge in the overflow tray (Figure G). When hot water leaks and is absorbed by the sponge, the resistance between the 2 bare copper wires drops to about 1MΩ or less. This forward-biases the 2 transistors and causes the piezoelectric buzzer to sound.

If you have multiple water heaters near each other, you can make a probe for each, and connect them all in parallel. You can also use this circuit under dishwashers, garbage disposals, refrigerator icemakers, swimming pools, hot tubs, waterbeds, etc.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F


G

Jeff Tregre (buildingultimatemodels.com) is an electrical engineer from New Orleans, La. He has over 20 years of professional experience in R&D, component design, assembly, and manufacturing, and is also interested in model building and robotics.

Abe Connally and Josie Moores

Toddler Swing

Make an indoor/outdoor swing for your little one in 30 minutes.

By Abe Connally and Josie Moores

EVERY TIME WE GO TO THE CITY, WE'RE obliged, at the insistence of our 2-year-old, to spend a considerable amount of time at a park, playing on the slides and swings. And when we get home, he repeatedly asks to go back to the "city swings."

So one stormy day when we couldn't play outside due to gale-force winds, we decided to make him his own swing indoors. It took us about 30 minutes to build using things we already had, and we've barely been able to get him out of it since.

1. Make the swing seat.

Cut the legs off the jeans, and place your toddler inside. The waistband should come above the waist but not up to the armpits. If needed, fold and sew the crotch to reduce the depth of the seat.

Bend the rebar into a circle, with the ends overlapping about 5", and feed it through the belt loops (Figure A). You want it to keep the jeans well open, but not stretched taut. Make sure the belt loops are securely sewn; they're the weakest part of the swing.

Wrap duct tape several times around the overlapped rebar ends.

2. Hang it by chains.

Check that the chain links will pass over the 2 sizes of quick link. If needed, you can widen a chain link by hammering a metal punch into it.

Tie the wire through the first chain link and use it to pull the chain through the hose

MATERIALS

Old jeans (1 pair) We used a 32" waist; for bigger jeans, use longer rebar.
Rebar, ⅜" diameter, 42" length
Chain quick links, 150lb+ rated: ¼" (2), ⅜" (2)
Chain, 3⁄16", 150lb+ rated two lengths, to loop over a tree branch or beam
Hose or tubing, ¾" diameter, 18" lengths (2) The chain must pass through it easily.

TOOLS

Scissors, needle, and thread
Duct tape
Tape measure
Adjustable wrench
Steel wire, 2' or baling wire
Optional: Metal punch, hammer, locking pliers or vise if you need to widen a chain link

CAUTION: **Do not leave your toddler unattended. He/she should hold on to the hose handles at all times.**

(Figure B). Have a friend help you, or tie the wire to something sturdy so you can pull against it. Then untie the wire.

Thread a ⅜" quick link through one leg of the jeans and around the rebar, bunching up the fabric inside the quick link. Put the end of the chain into the open quick link, and tighten the quick link with the wrench (Figures C and D).

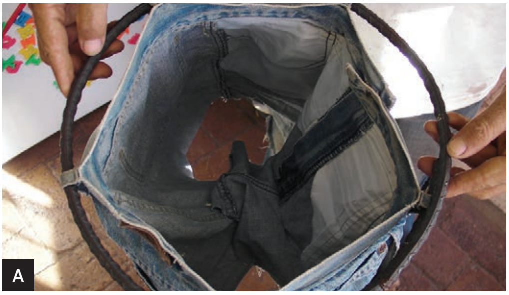
Prepare the second chain the same way on the other side of the jeans (Figure E).

Hang the chains over a sturdy branch or rafter, then attach each chain to itself using a ¼" quick link, tightened with the wrench. Tie any extra chain in a knot for added security (Figure F).

3. Test for safety.

Put weight on the swing to assure yourself that everything is secure and safe. Then let your toddler try it out.

A whole other how-to is required to get your toddler to leave the swing.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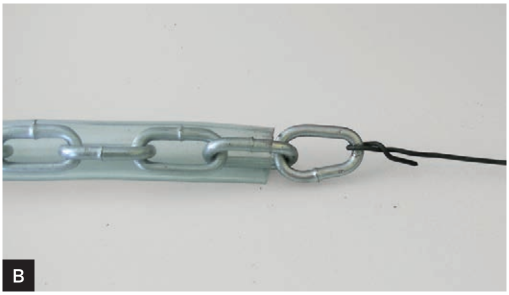
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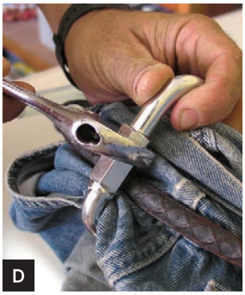
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F

Abe Connally and Josie Moores are an adventurous couple living in an off-grid hideaway with their two boys. Their experiments with energy, architecture, and sustainable systems are documented at velacreations.com.

Solar Pendulum

Sunshine is all you need to get this easy-to-build pendulum swinging.

By Owen Tanner

IF YOU'RE STUCK FOR SOMETHING TO DO on a rainy weekend then this might be the perfect thing to build, ready for when the sun comes back out. The pendulum is self-starting, meaning that when light hits the solar panels it'll start swinging all by itself. There's something a bit magical about watching it swing ever higher with no visible help, which is the main reason I decided to build one.

The inner workings of my pendulum are built around a circuit that appeared in the book *Junkbots, Bugbots, and Bots on Wheels*, co-authored by the father of BEAM robotics, Mark Tilden. BEAM stands for biology, electronics, aesthetics, and mechanics, and it's a style of robot-making that uses simple analog circuits rather than microprocessors (*see MAKE Volume 06, page 76*).

BEAM bots generally use simple electronic components, and they're often solar powered. Another hallmark of BEAM bots is that their behavior is usually more complex than their simple components would suggest, and this pendulum is no different.

The pendulum itself consists of a neodymium magnet suspended above a coil of wire using fishing line. Capacitors in the base store energy from the solar panels, which is dumped into the coil below the magnetic pendulum by transistors. The magnetic field generated by the current flowing in the coil attracts the hanging magnet, starting it swinging. With every swing the magnet gets another pull from the coil, lifting it higher and higher.

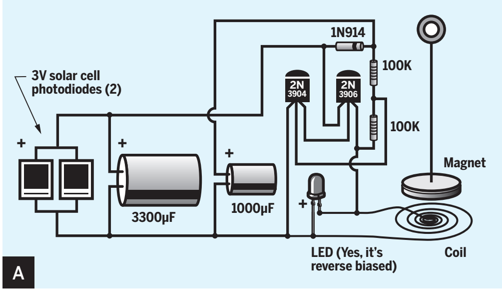
Owen Tanner

MATERIALS

Wooden box for the base
Brass tubing, 5mm diameter, 40cm length
Neodymium magnet, disc-shaped, 25mm×3mm
LED, red, 5mm
Coil, 1mH Solarbotics part #CMH, solarbotics.com
Solar cells, 3V output (2) used in parallel, such as Solarbotics #SCC2422 or salvaged cells from calculators
Capacitors, electrolytic: 3,300µF (1), 1,000µF (1)
Transistors: 2N3904 type (1), 2N3906 type (1)
Resistors, 100kΩ (2)
Diode, 1N914
Copper wire, thin enameled, several feet I used wire that was 0.45mm diameter, but any will do.
Monofilament fishing line, a few feet
Cotton thread or string for binding the fishing line
Assorted brass bits for decoration
Epoxy glue
Cyanoacrylate (CA) glue (optional) aka super glue

TOOLS

Soldering iron, solder, flux paste, scissors, sandpaper, hacksaw or jeweler's saw, electric drill, 3mm and 5mm drill bits, vise or drill clamp, thick gloves, blowtorch (optional)



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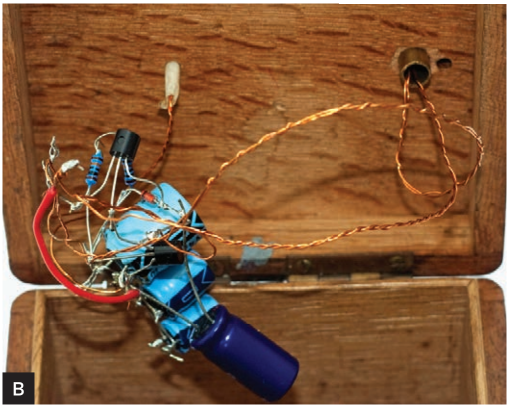
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An LED connected across the coil takes advantage of the back EMF (counter-electromotive force) generated when the moving magnet passes by. This energy is harvested and used to flash the LED with every swing. The cycle continues as long as the sun is shining.

With no batteries to replace, this pendulum will run for years without maintenance.

1. Assemble the circuit.

Build the circuit, following the schematic (Figure A). This should be simple if you've had any previous soldering experience, as there are only a few components. I've gone for a slightly shambolic approach to this circuit (Figure B) as I knew it was going to be hidden away, so feel free to be much neater than me. It doesn't need to be pretty to work, though, so don't feel intimidated if you've not had much experience building electronic circuits.

To connect the LED, solar panels, and coil, you may want to use crocodile clips rather than soldering, so you can test the circuit before assembling it. I made long extension cords for these parts using twisted pairs of enameled copper wire to allow me to run them through the brass arm and then down through the holes in the base box.

To test the circuit, you can use any 3V DC power supply in place of the solar panels if there's no sunshine. You should be able to tape a magnet to a piece of thread and, holding it above the coil, trigger the magnetic pulses. This will cause your magnet to start swinging and will also light the LED as it passes back past the coil.

2. Construct the brass arm.

Cut 2 lengths of brass tubing: 30cm for the vertical section of the arm and 10cm for the horizontal section. Clamp the vertical tube in a vise, and drill a 5mm hole 10mm from one end. You'll run the LED wires through both tubes, via this hole. Be careful not to drill all the way through the tube; if you're using a drill press, it's helpful to set the depth stop before drilling to prevent this happening.

Next, join the 2 sections of tubing at right angles by brazing (soldering) them together.

If you have a low-powered soldering iron, you may have trouble. Mine is only 25W and it did OK, so anything above that should be fine.

Before soldering, clean the areas to be joined by roughing them up using coarse sandpaper. Sand the end of the horizontal tube, and all around the hole in the vertical tube.

Next, stick some solder onto the 2 tubes before you attempt to join them. This is where the flux comes in. Tackling one piece at a time, liberally apply a coating of flux at the joining point, and then heat the area with the soldering iron while feeding solder into the area. When the tube is hot enough, the solder should begin to flow around the area to be joined.

Once each piece has a coating of solder, they can be brought together and reheated. Clamp the vertical tube to stop it rolling around, and hold the short tube with pliers or thick gloves. You may find it useful to use a blowtorch instead of a soldering iron to gently heat the pieces while you push them together (but be careful, too much heat may discolor the metal).

You'll now have the 2 pieces joined at right angles (Figure C). If you have masses of solder at the joint, just sand it down nice and smooth.

C

D

E

CAUTION: When using power tools, always wear eye protection, work slowly and carefully, and follow the operation and safety instructions in the owner's manual.

3. Drill the base.

Position the brass arm and the coil on top of your box so the coil lies approximately beneath the midpoint of the horizontal tube (Figure D). Once you've found positions that look right, mark the positions for the holes on the box. As the wire coil has a hole in its center, you'll probably want to offset the drill hole for this so it's hidden under the coil.

When you're happy with the layout, drill a 5mm hole for the brass arm. It should be a snug fit. A smaller drill bit of 3mm can be used to make the hole for your coil wires to go through. Lightly sand both holes to remove any rough edges.

4. Make the pendulum.

My pendulum is constructed using some old brass gears to hide the neodymium magnet. The main gear is 45mm in diameter, with a smaller gear stuck on top for decoration. The magnet and gears are attached using epoxy glue, which is more than strong enough to hold everything together.

For hanging the pendulum, I added a short loop of the enameled copper wire. I simply looped it through the holes around the edge of the gear, wrapped the loose ends back around to secure it, then bent it upward to form a peak in the middle (Figure E). Depending on the weight of your pendulum you may need to use slightly stiffer wire for a hanger, to stop it deforming as it swings to and fro.

5. Wire it all together.

This is the tricky bit. The wires for the LED and solar panels must be threaded through the brass tubing and down into the box. I found it best to thread the LED wires first as they're the most difficult. Push them through the short brass tube, wiggling until you can see them come out into the vertical tube.

Next, take a short length of copper wire and make a small loop in the end, creating a makeshift needle (or use an actual needle if you like). Tie a length of cotton thread to this loop and drop your needle down the vertical tube.

Make a slipknot in the thread and slip it around the LED wires; with careful maneuvering you'll be able to pull it tight around the wires. Now pull the wires down through the vertical tube and push-fit the tube into the base. (I added a decorative disk at the base.)

The solar panel wires can then be worked down alongside the LED wires with a bit of jiggling (Figure F).

Finally, push the coil wires through their hole and solder them into the circuit, along with the LED and solar panels (Figure G).

6. Hang the pendulum.

Originally I hung the pendulum using the enameled copper wire, but it snapped after constant swinging fatigued it. I switched to fishing line and haven't had any trouble since.

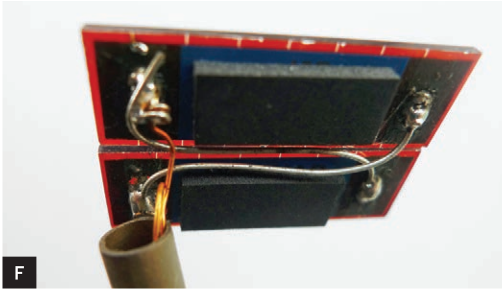
Tie one end of the fishing line to the brass arm, thread the line through the wire hanger on the pendulum, and then loop it back up over the arm and tie it to itself using a slipknot. This will allow you to make adjustments to the height of the pendulum above the coil.

To keep the line from moving around on the brass tubing, wrap cotton thread around the tube many times, on both sides of the line, until you've built up a tight and secure lashing, then tie off the thread and trim the knot (Figure H).

If the slipknot on your pendulum isn't tight enough, add a drop of super glue to fix it in position when you're happy with the height.

Operation and Troubleshooting

To operate the pendulum, simply set it in the sunshine on a sunny day. If the pendulum doesn't start moving, try the following:



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» Adjust the positioning of the magnet. Hang it so that it's not aligned directly above the coil. It should be off to the left or right slightly, but not so much that the magnet doesn't overlap the coil at all.
» Experiment with the vertical distance between the coil and the magnet.
» Check the connections of the transistors, which handle the switching of the coil.
» Make sure there are no other magnetic materials around where you're building and testing the circuit that might be causing it to trigger. Something like that is easy to overlook and can cause hours of head-scratching.

Owen Tanner is a compulsive maker and experimenter who loves to create new things. He and his good friend Greg Tudor document their projects at accomplished.org.


BUBBLE TROUBLE
BUBBLES ARE A GREAT WAY TO FIGHT BOREDOM. HERE IS THE SOLUTION:
10 CUPS WATER
1 CUP DISH SOAP
1/4 CUP GLYCERIN
BUBBLES EXIST WHEN THE AIR PRESSURE INSIDE THE BUBBLE IS IN PERFECT BALANCE WITH THE AIR PRESSURE OUTSIDE.
THE SOAP, CALLED A LIPID, MAKES A THIN LAYER PROTECTING THE WATER.
WATER
LIPIDS ORGANIZE INTO A PROTECTIVE LAYER BETWEEN THE WATER AND THE AIR.
SOAP LIPID
WATER
SOAP LIPID
SINCE THERE IS ONE LAYER ON EACH SIDE, SCIENTISTS CALL THIS A LIPID BI-LAYER.


HOWTOONS.COM
USING WIRE AND STRAWS WE CAN MAKE BUBBLES WITH ALL KINDS OF GEOMETRY. TRY TRIANGLE, SQUARE, AND HEXAGONAL FRAMES!
GET CREATIVE! INVENT YOUR OWN BUBBLE MAKER.
PLASTIC SIX-PACK RINGS
SODA BOTTLE SLICES
BOTTOMLESS PAPER CUPS
LET'S HAVE SOME GOOD CLEAN FUN!

By Donald Simanek, Recreational Physicist

The Slow Fall

Dropping a magnet through an aluminum tube takes longer than you'd think. Why?

GALILEO SHOWED THAT FALLING BODIES descend to earth with constant acceleration. Unsupported bodies, like stones, fall downward with an acceleration of about $32\ ft/s^2$ if air drag is negligible. Some bodies, like falling leaves, do fall more slowly, but usually not in a straight line.

So a body falling slowly downward in a straight path, with constant speed, is something we're not used to seeing. One way to make this happen is to drop a solid body into a container of transparent, viscous material, such as glycerin. But it's far less messy to use electromagnetic induction.

Very strong neodymium-iron-boron (NdFeB) rare-earth magnets are available in many sizes in cylinder, disk, and sphere shapes. They're relatively inexpensive. Such a magnet, when dropped down a vertical nonferrous metal tube, will descend surprisingly slowly. What happened to constant acceleration?

Drop a small rubber ball down the tube to demonstrate how quickly it falls. Then drop the magnet down the tube. People expect it to emerge quickly, but it takes its sweet time. Some suppose it's stuck. As it finally emerges from the bottom of the tube, it then speeds up. (Catch the magnet in your hand as it leaves the tube, or let it fall into a padded box, to prevent it hitting the floor and shattering.)

If the magnet is small enough, it can be dropped down the tube in any orientation. Note that if it's dropped in edgewise, it will turn as it falls and emerge oriented with its poles along the up/down line.

You can buy a complete apparatus for this experiment from scientific supply houses, consisting of a 5'-long aluminum tube and a strong cylindrical magnet that fits loosely inside the tube. Some commercial versions, with shorter tubes, have holes in the tube's side so you can watch the magnet's slow progress.

You can make your own apparatus for less cost — 1"-diameter aluminum tubing is available in hardware stores in 6' lengths, and a ¾"-diameter cylindrical magnet fits loosely inside (Figure A). The tube can be any nonferrous metal of good conductivity, such as copper or aluminum; shorter tubes work too, and ½" OD tube can be used with a 7/16"-diameter magnet.

The Reason

So why does the magnet fall so slowly? The moving field of the magnet exerts force on free electrons in the metal tube, setting up induced electron currents around the circumference of the tube. Moving electrons have a magnetic field of strength proportional to their speed. The magnetic field of all these moving electrons acts in a direction to oppose the motion of the magnet.

This is an example of Lenz's law: *A changing magnetic field induces currents in conductors. These induced currents produce a magnetic field that opposes the change that induced it.*

Lenz's law is a consequence of Newton's third law, which says that if body A exerts a force on body B, then B exerts an equal but oppositely directed force on body A. You could get into the messy details of the laws of these fields, currents, and forces, but Lenz's law says it all concisely: "An induced current is

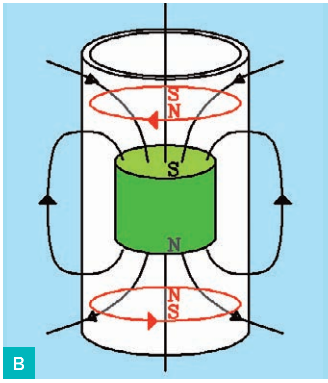


Fig. A: Dropping the magnet into the tube.

Fig. B: The magnetic field of induced electron currents around the circumference of the tube acts in a direction to oppose the motion of the magnet.

always in such a direction as to oppose the motion or change causing it."

This applies to the magnet falling in the tube as well as all the variations of this demonstration described below. If a cord were attached to the magnet and it were pulled *upward* through the tube, the induced currents would exert a *downward* force on it, opposing the magnet's motion as Lenz's law predicts. Isn't nature perverse?

So the motion of the falling magnet is opposed by the upward forces due to these induced currents. The size of the induced currents *very quickly* increases until the upward force on the magnet equals the downward force due to gravity. But by the time this happens, the magnet is already moving downward, so it continues to move downward at constant speed, because the net force (gravity plus magnetic) on it is now zero, its acceleration is zero, and its speed is constant.

Figure B gives a schematic idea of what's going on, at the introductory physics level. A few of the falling magnet's field lines are shown (in black). Where these intersect the walls of the metal tube, they exert force on free electrons, inducing currents all along the tube's length near the magnet. Only two of these current loops are shown (in red). These current loops produce magnetic fields as if they were magnets, with polarities as shown (in red). Like magnetic poles repel; opposite poles attract. So these currents exert forces upward on both the magnet's N and S poles.

Of course this is a simplification; there are details involving the Lorentz force on moving electrons that we'll spare you. What's really interesting is that the other demonstrations described below all depend on the same laws of physics, but the geometry is very different.

CAUTIONS: **Rare-earth magnets are very strong compared to their weight and can affect objects more than a foot away. Do not place them near credit cards, computers, VCRs, TVs, cellphones, pacemakers, computer disks, magnetic tape, or any magnetic computer storage media.**

The nickel plating prevents scratching and chipping of the magnets, but they're still fragile and shouldn't be allowed to strike each other or other objects; small, sharp chips could be knocked off.

Treat small magnets just as you treat prescription drugs: do not put them where children or pets can find them and potentially put them in their mouths. A swallowed magnet will pass, but if two magnets are swallowed separately, or if a magnet and a ferrous metal object are swallowed, they can be attracted to each other with an intestinal wall between, perforating the intestine.

Falling Sphere

Magnetized, nickel-plated rare-earth spheres are also available from many internet sources. Obtain such a spherical magnet slightly smaller than the inside diameter of the tube. The sphere will fall slowly down the tube just as the cylinder did.

Mark the magnet "poles" with small colored stickers. Now watch the sphere from above as it falls down the tube. Does the sphere always rotate and reorient so that one of the poles is up and the other down? Or does it reorient with the magnetic axis horizontal? Why?

The Visible Slow Fall

The trouble with the previous demonstrations is that you can't *watch* the magnet during its fall and can't appreciate that nearly the entire

Donald Simanek

fall is at constant speed. So I devised an improved version with several advantages.

I use a 4'- or 5'-long bar of aluminum, with a $\frac{1}{10}$"×$\frac{3}{4}$" cross section (they cost only a few dollars) and two cylindrical plated rare-earth magnets, 11mm in diameter by 5mm thick (about $1 each). The package says each will lift 5lbs. Using a soft iron strap about $\frac{3}{4}$" wide, I fashion a rectangular frame about $\frac{5}{8}$"×$1\frac{1}{4}$". The magnets hold themselves on the inside of the frame, leaving their exposed poles about 5mm apart, with their attracting poles facing each other. Once assembled, the entire thing acts like a single magnet with a small gap between opposing poles (Figure C). This frame fits loosely over the aluminum strip. When dropped, it glides gently down the strip at slow and constant speed.

Even easier to make is the version shown in Figure D. I used a small plated-steel bracket that's one of the standard parts in Meccano construction sets. Because it's a bit heavier on one side, you need to hold the aluminum bar at a slight angle to the vertical so the falling magnets don't wander offside (Figure E).

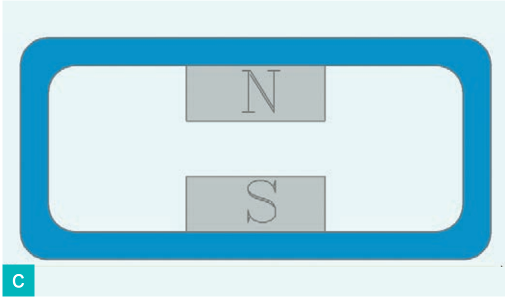
These "open" versions have another advantage. You can hold the frame in your hand and move it back and forth along the aluminum strip, feeling the opposition of the forces to the magnet's motion.

Notice that in both these demonstrations, the magnet aligns itself to fall without touching the aluminum tube or strip, so there's negligible friction.

Simpler and Simpler

Rare-earth magnets are also available in ring (donut) form. Find one that just fits loosely over an aluminum rod, and it will fall slowly down the rod (although I find that this version of the demonstration isn't as dramatic in its speed reduction as the other versions described here).

I like to put a colored wooden bead on the rod, below the donut magnet. Release both at once. The bead falls quickly; the magnet takes more time. It's a hare and tortoise race toy. Invert the rod, and the bead and magnet fall slowly, the bead riding on top of the magnet.



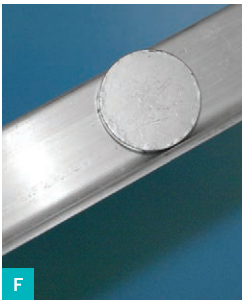


Fig. C: "Open" magnet assembly: 2 cylindrical magnets in an iron frame.

Fig. D: Another "open" magnet assembly, using a steel Meccano bracket.

Fig. E: Magnets falling (slowly).

Fig. F: Magnet rolling down an aluminum track (slowly).

Slow Rolling

Here's a way to make a strong disk magnet roll slowly, using 1" angle aluminum stock (a standard hardware store item in 6' or 8' lengths). The disk magnet (magnetized along its cylinder axis) rolls with one face close to one face of the aluminum track (Figure F).

The aluminum angle stock can also be used as a track for spherical magnets. As with most of my projects, dimensions generally are not critical. Be creative.

For more fun with Lenz's law, build the Aluminum Levitator from MAKE Volume 24 (makeprojects.com/project/e/1291).

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.

TOY INVENTOR'S NOTEBOOK

Invented and drawn by Bob Knetzger

You can make it!

"Level Best" 3D Camera Slide-Bar Hack

FOR TAKING 3D PHOTOS WITH A regular camera, you need a tripod and stereo photo slide bar. Professional slide bars cost $50 or more, but you can make a DIY slide bar fast and cheap that'll work just as well. Here's how:

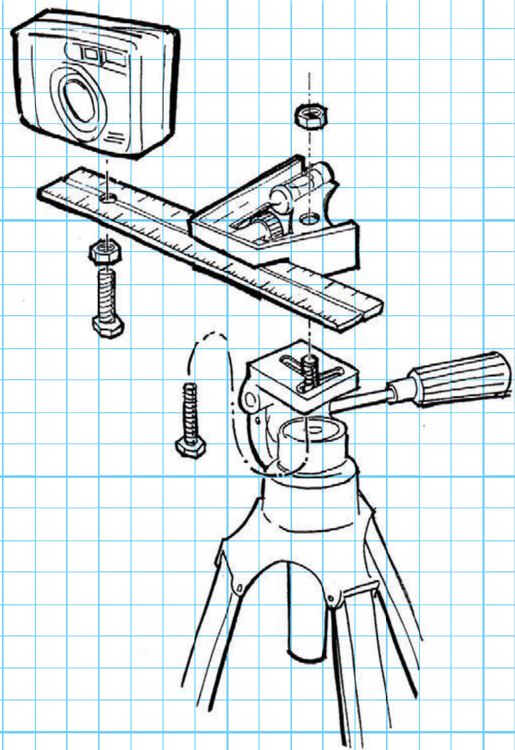
1. Hack a T square level. Use one with a frame that's big enough to sit flat on the top of your tripod. Drill a hole in the level to fit on the tripod's stud, or if needed, use a ¼"-20 bolt and nut to attach it to the tripod.

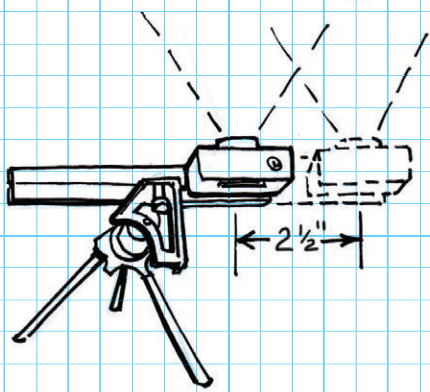
2. Drill another hole near the end of the steel rule to hold your camera. Attach the camera with a ¼"-20 bolt and nut. Carefully thread the bolt into the camera's socket, then tighten the nut under the rule to secure the camera. You're done!

3. To take 3D photos: Level the camera on the tripod. Loosen the thumbscrew and slide the bar so the camera is against the tripod head. Retighten the screw and take one picture. Loosen the screw, slide the camera bar over 2½" (standard intraocular spacing for 3D picture taking), and retighten. Take your second picture. Now you have a stereo pair of images, one for each eye.

You can print the pictures side by side for "free viewing" (hold the print at arm's length and cross your eyes; adjust your gaze so you see 3 boxes — the center, overlapped image will "pop" into 3D), or use Photoshop to combine the images into a red/green anaglyph and view it with red/green glasses (here's a tutorial: opentutorial.com/make_3d_images).

Bob Knetzger is an inventor/designer with 30 years' experience making all kinds of toys and other fun stuff.





+ To make your own View-Master reels, I refer you to Shab Levy's slick kit with everything you need: empty reels, software templates, a mounting rig, and complete instructions: makezine.com/go/shab. Check out my article on View-Master on page 58 of this issue.

DANGER!

By Gever Tulley with Julie Spiegler

Make a Slingshot

Create your own primitive tool.

1. Make elastic bands. To begin, tie 2 rubber bands together to make a long band. Repeat. If you find you want more power later, you can double up the rubber bands.

2. Make a pocket. Cut a small rectangle out of a scrap of leather or sturdy cloth. You can either tie the rubber bands to the pocket, or cut 2 small holes and loop the bands through.

3. Assemble. Tie the rubber bands to the ends of a forked stick. If the bands slip off, try lashing them in place with a bit of string.

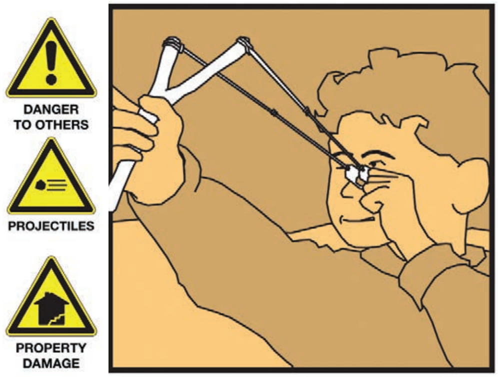
4. Aim. Place a pebble in the pocket and trap it by pinching the pocket with thumb and forefinger. Hold the handle steady at arm's length. Keep a light, but firm, grip on the pocket and pull back.

5. Fire. Release the pocket!

Slingshot masters say that the key to aiming is to hold the pocket steady and move the forked stick around to line up your shot. Aluminum cans make good targets: set 'em up and knock 'em down.

Accuracy comes from repetition. Gather a pile of pebbles and spend a few minutes every day aiming at a variety of targets. A slingshot master can hit a soda can from 20 paces.

Excerpted from *Fifty Dangerous Things (You Should Let Your Children Do)* by Gever Tulley with Julie Spiegler (fiftydangerousthings.com). Gever is co-founder of Brightworks, a new K–12 school in San Francisco (sfbrightworks.org).



Gever Tulley

WARNING: Slingshots aren't inherently very dangerous, but releasing projectiles can be. Always know where you are pointing your slingshot and NEVER aim in the direction of a person or pet. You are responsible for every projectile you release.

REQUIRES
Forked stick
Rubber bands, medium-sized
Scrap of leather or cloth
Pebbles, peas, or flower buds
Clear area without people, pets, or things that might get damaged

DURATION
Short

DIFFICULTY
Moderate

SUPPLEMENTARY DATA

- The slingshot is a fairly modern invention, as these things go. It requires long, thin strips of stretchy rubber — a material produced first in the late 1800s and not widely available until the early 1900s. The idea is really an update of the ancient sling (a leather pocket tied to 2 leather strips), the weapon purportedly used by David to bring down Goliath.
- Rubber got its name from Joseph Priestley (inventor of soda water), who noticed that blobs of it were good for rubbing pencil marks off paper.
- If there was no air resistance to contend with, a pebble fired from a slingshot would travel in what is referred to as a ballistic trajectory. From the moment the pebble leaves the pocket of the slingshot, gravity bends its path down towards Earth. Put the air back into the equation and the path gets even shorter. Without air resistance, your pebble would travel almost twice as far.

Arduino meets iPhone at last! Plus top tools, tech toys, model makers' mags, gastronomy, gardening, and gaming geeks.

TOOLBOX

LEGO TECHNIC CONTAINER TRUCK 8052

$70 **lego.com**

Lego's Container Truck set lets you build a cool and detailed model equipped with a battery pack and motor. Pull the lever and the truck unloads the container behind it. Pull the lever forward and it loads it back on. However, the kit's true potential lies in all the work Lego has put into its Technic products, which it conceived as a way of bringing robotics to Lego.

Technic beams feature peg-style connections rather than the classic studs of System bricks, making for stronger models that are less likely to break apart when the motors start spinning.

While Lego's fabulously successful Mindstorms NXT set uses the beams to build its robots, Technic has its own robotics components, a line called Power Functions, that in some ways rivals its more famous cousin. It features a variety of DC motors, switches, battery packs, and actuators far more diverse than what NXT offers. These, combined with Technic's robust assortment of gears and axles, make robot building a cinch.

If that weren't enough, the Container Truck kit features one rare and useful part: a linear actuator. This is a rod that extends or contracts when the axle socket is spun, making it great for robotic limbs and other projects employing linear motion. The actuator was released in 2008 and only nine sets feature its goodness, giving you another reason for grabbing this set.

—John Baichtal

Autodesk 123D Sculpt

Free **makezine.com/go/123d**

This has quickly become my new favorite iPad app. It's a free, scaled-down version of Autodesk's 123D beta, with plenty of features. I dashed straight to the stock head shape and started making Mr. Random Demon Dude.

The deformation tools are robust, allowing you to push, pull, pucker, and paint. Texturing tools allow for "rubbing" more than 60 patterns onto your mesh or importing your own pictures. Saving and duplicating your sculpts enables you to essentially create your own stock library. Export and share your creations as transparent *.png* files or as 720p HD turntable movies. *—Jason Babler*

Fuji Instax Mini 50S

$120 **makezine.com/go/instax**

The retro-styled, piano-black Fuji Instax Mini 50S is a newfangled instant camera. Instax cameras are not new, but Fuji loaded the 50S with smart features. The lens is amazing and includes a detachable macro-like lens. The flash is intelligent and can be tuned for different lighting levels. A brilliant self-timer encourages sharing by snapping two shots. As the film quickly develops, the richness of the colors surpasses expectations.

With billion-megapixel cellphone cameras everywhere, and the Hipstamatic trend still gaining popularity, the Instax Mini 50S might seem redundant. But its usefulness extends into a realm that digital can never touch. Surprising friends with an instant memory never gets old, and holding a printed photo is just a great feeling. These photos beg to be given away.

—Brookelynn Morris

GET BUCKY

$25–$40 **getbuckyballs.com**

Buckyballs — the toy, not the C60 molecule — are sphere-shaped rare-earth magnets that serve as a stress relief toy, a mini building set, and fridge decoration. The Original Edition set I played with packed 216 of the little guys, making for a malleable metallic lump the size of a golf ball. Have fun, but remember that rare-earth magnets and kids do not mix. *—J. Baichtal*

GARDEN WORKS ANGLE WEEDER

$15–$20 **garden-works.net**

I'm a compulsive weeder; I have been known to de-dandelion hotel lawns and local parks. While a fork or even a stick will do, the best tool I've ever found for the job is Garden Works' Angle Weeder. Available for right- or left-handers, it has wicked little prongs for getting under the leaves of dandelions, small thistles, crabgrass, etc. The angle provides the perfect lever for uprooting them completely. If only it would fold up in my back pocket, my life would be complete!

—Arwen O'Reilly Griffith

Eureka! By Roy Doty
Phfft!

Ephrem's Bottle Cutting Kits

$39 (original), $44 (deluxe) **ephremsbottleworks.com**

Cutting glass is tricky! Luckily, this bottle cutting rig does an excellent job of evenly scoring the glass — next to impossible to do freehand. I was grateful for Ephrem's suggestion to use alternating hot and cold tap water, resulting in predictably clean breaks. I now have an unlimited ability to make drinking glasses, bowls, and even food storage containers out of my recycling! *—Meara O'Reilly*

Bosch 10" Table Saw GTS1031

$400 **boschtools.com**

The 10" portable table saw from Bosch is great if you're limited on space or need to move your workshop from place to place. A one-handed carrying handle is built into the rigid steel frame, and the fence, blade guard, miter gauge, push stick, and wrenches all snap into place under the table.

This small package has plenty of bite from the 4HP electric motor spinning at 5,000rpm, and comes from the factory with a sharp 24-tooth, 10" carbide blade. The tabletop expands and allows you to rip pieces up to 18" in width. This versatile saw is ideal for DIY or home projects, especially if you're concerned about storage space but still want the power and functionality of a larger table saw.

—Nick Raymond

REDPARK BREAKOUT PACK FOR ARDUINO AND IOS

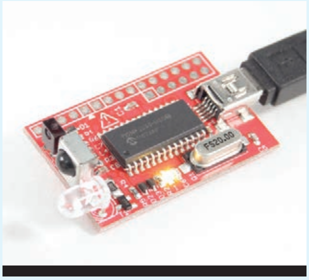
$80 (kit), $59 (cable only) makershed.com

Apple made big news again in July when it approved, for the very first time, a general-purpose serial cable for the iPhone, iPad, and iPod touch. On one end, it's got a dock connector to plug into your iOS device. On the other, it has an RS232 port that you can easily connect to Arduino or any other gadget that speaks a serial protocol.

At the Maker Shed we've put together a breakout pack that includes the cable, an RS232-to-TTL serial adapter (so you can connect the Redpark Serial Cable for iOS to an Arduino), and the Mintronics Survival Pack (to supply you with components and sensors to play with).

With the breakout pack and an Arduino, you're ready to build apps that connect your Arduino and iOS device. We've prepared a guide at Make: Projects (makeprojects.com/project/c/1130) to take you through a simple project with this kit, controlling the Arduino's LED with a switch button on the iOS device's screen. It's just the beginning.

—Brian Jepson

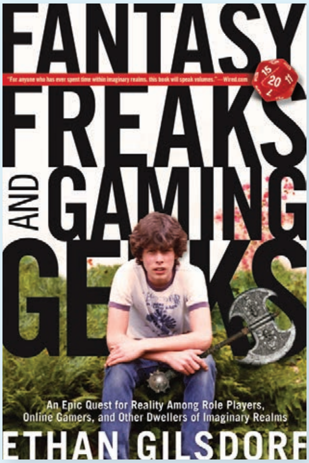


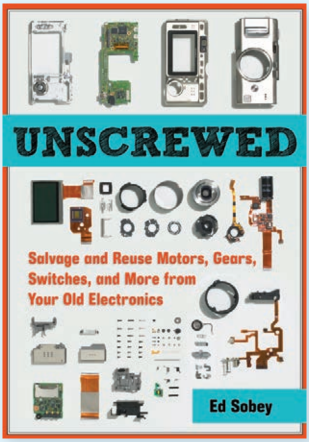
USB INFRARED TOY V2

$20 dangerousprototypes.com

This is an open source device not much larger than a postage stamp that lets you explore the invisible world of infrared communication. It's a fully assembled IR monitoring and analysis tool that opens up unlimited possibilities. You can receive IR signals, remotely control your computer, view IR signals on a logic analyzer, and capture and replay remote-control buttons from any device's IR remote (think TVs!). Dangerous Prototypes is always working on updates. Support from the company is great, and new hacks are regularly posted on its forum.

—L. Abraham Smith, N3BAH





A World of Your Own Making

***Fantasy Freaks and Gaming Geeks* by Ethan Gilsdorf**
$25 **The Lyons Press**

In 1978, Ethan Gilsdorf's life took a dramatic and scary turn when his mother suffered a devastating brain aneurism. He was ripe for escape, and it came one day in JP, the nerdy new kid from across the street. JP whisked Ethan into another dimension, one of limitless mental invention and adventure, called Dungeons & Dragons. Ethan grew out of his D&D obsession by college, but a chance rediscovery of his massive D&D collection sent him on a new quest: to find out what purpose fantasy "escapism" serves others.

So, he set off on a journey around the world to meet gamers, Tolkien fanatics, live action role-playing (LARPing) enthusiasts, Potter fans, and others. The result is a surprisingly moving memoir and ode to geek culture. It's also a great book to give to friends and relatives who don't understand the appeal of this subculture. I, for one, am glad that my drawstring bag of RPG dice is still always at the ready. This book rolled a natural d20 (and the wonderful design gets a +2 bonus).

—Gareth Branwyn

Hidden Treasure

***Unscrewed* by Ed Sobey**
$17 **Chicago Review Press**

According to Ed Sobey's *Unscrewed*, there's gold inside the electromechanical detritus left by the curb for the trash collector.

Take, for example, the obsolete inkjet printers cluttering many a basement. There are all sorts of maker treasures inside — motors, gears, pulleys — and Sobey provides instructions on liberating these parts for reuse.

Tiny motors inside a scrapped digital camera can be made to drive very small, solar-powered kinetic sculptures, while microswitches inside a computer mouse can be re-engineered to play a chime, turn on a light, or power a motor. Want to build a model car or boat? The solar cells in that old emergency radio could come in handy. Convert an old popcorn popper into a coffee roaster, or pillage an electric toothbrush to create a working submarine toy. The wheel of mechanical life turns round and round.

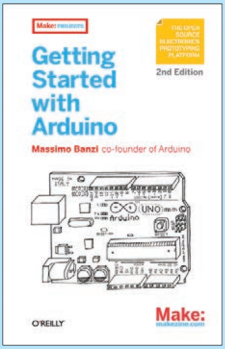
—William Gurstelle

New from MAKE and O'Reilly

Making Things Talk, 2nd edition

by Tom Igoe
$28–$35 pre-order O'Reilly Media

Building electronics projects that interact with the physical world is fun, but when the devices start to talk to each other, things really get interesting. Here are 33 easy projects perfect for people with little training but a lot of interest.



Getting Started with Arduino, 2nd edition

by Massimo Banzi
$15 pre-order O'Reilly Media

Join the legion of hobbyists who have discovered this incredible (and educational) electronics prototyping platform. Written by the co-founder of the Arduino project, *Getting Started with Arduino* gets you in on all the fun!

ARTISTRÉ MOLECULAR GASTRONOMY EXPERIMENTAL KIT

$59 forthegourmet.com

I've been dabbling in scientifically derived cooking techniques. Call it modernist cuisine or molecular gastronomy — either way, one of the hard parts is procuring unusual ingredients without buying in bulk. The Artistré kit offers 12 different 50g ingredient packs to get you started.

—JEP

The Kitchen's Cutting Edge

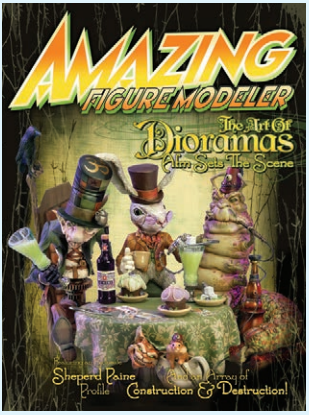
***Modernist Cuisine* by Nathan Myhrvold, Chris Young, Maxime Bilet**
$625 The Cooking Lab

The Codex on Cooking has arrived. Former Microsoft CTO and polymath chef Nathan Myhrvold has created the definitive work on modern cooking. This gorgeous six-volume set demystifies cooking techniques, ingredients, and equipment. You gotta love their use of water jets and band saws to bisect grills, microwaves, and pressure cookers so we can view their guts in stunning cutaway photos.

While I can't replicate every technique (their bewitching pea butter will remain out of reach until I borrow a laboratory centrifuge), many I can. I followed their Modernist Mac and Cheese recipe, which eschews cream for iota carrageenan and sodium citrate to achieve a cheesier, less muddled, yet stable sauce. It was modern, comforting, and delicious. And it improved my understanding of elevating food to its highest levels.

The price tag may be a bit hard to swallow, but at 2,458 pages, that's only 25 cents per page to own perhaps the best cookbook ever written!

—John Edgar Park



Like a lot of kids in the 60s and 70s, I started assembling plastic model kits as soon as I was old enough to know better than to huff the plastic cement. I don't do much modeling anymore, but I still regularly buy modeling magazines and marvel at the hobby from a distance. —*Gareth Branwyn*

Amazing Figure Modeler

$28/4 issues **amazingmodeler.com**

This is my all-time favorite modeling magazine, which mainly covers the custom resin-kit scene. The kits are usually made and sold in small productions by individuals, then the buyers go crazy, modify the kits, and build absurdly detailed dioramas around them (all lovingly chronicled in the pages of *AFM*). Tons of kit reviews and detailed how-tos in every issue.

Airfix Model World

$65/12 issues **airfixmodelworld.com**

This thick, slick U.K. model monthly is something of a house organ for the Airfix model brand, but they do cover other kits. And although they make a point of stating on their website that it's for "all scale modellers," it mainly covers the planes of its namesake.

Amazing Vehicular Modeler

$10/issue **amazingmodeler.com**

This new biannual publication from the folks at *Amazing Figure Modeler* does for vehicle kits what *AFM* does for character models. Cool conversions and dioramas for the Batmobile, the Monkeemobile, the Mysterion, the Munster Koach, and other car-kit classics.

FineScale Modeler

$40/10 issues **finescale.com**

This venerable modeling magazine focuses on military models, with lots of tutorials, shop tips, and plenty of reviews where the "experts" build and critically review new kits.

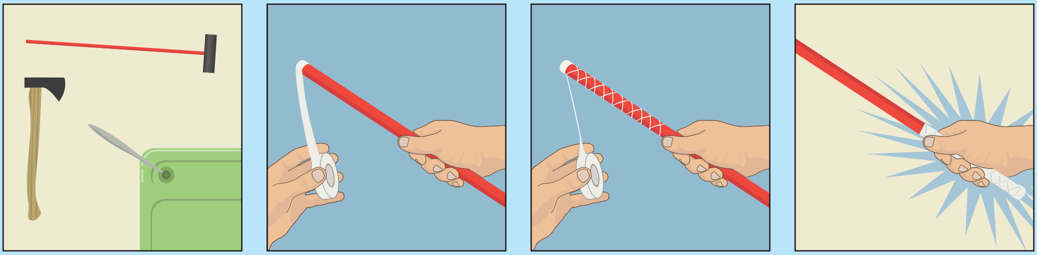
Scale Aircraft Modelling

$127/12 issues
scaleaircraftmodelling.com

Another U.K. favorite, SAM goes very in-depth on the planes behind the models as well as the models themselves, with aviation profiles, pullout plans, insignia, and color schemes. A must for the serious aviation modeler.

Tricks of the Trade By Tim Lillis

Get a grip!



Makers have a lot of tools, and tools have handles. Use this trick — an old favorite of firemen, and hockey and bike polo players — to get a good grip.

First, using hockey tape, build up a knob at the end of the tool to ensure that the handle can't slip out of your hand.

Next, twist some tape so it forms a cord-like shape, and wrap your handle down and back up to the knob, crisscrossing the tape.

Cover the crisscrossed area with flat tape and you'll have a sure grip every time!

Have a trick of the trade? Send it to tricks@makezine.com.

Super Soaker Thunderstorm

$15 **hasbro.com**

Two interesting innovations are built into Hasbro's newest squirt gun: first, they ditched the classic reservoir in place of a system of swappable 10oz/300ml clips. Ten ounces may not seem like much, but when you have extra clips on your belt, you'll find yourself reloading much more rapidly than the old dip-into-the-swimming-pool method. Second, they added a battery-powered peristaltic pump, which forces the water out at high velocities.

The Thunderstorm offers fascinating hacking options. To squirt more water out in the same amount of time, you have only to up the volts running to the pump. Another mod could involve ditching the clip in favor of a larger reservoir. And peristaltic pumps can be food-safe, making it possible to reuse them for dispensing beverages. Hello, drinkbot! *—J. Babler*

Jason Babler is senior art director of MAKE, an avid gamer, and a beer maker.

John Baichtal writes for MAKE, makezine.com, and geekdad.com.

Gareth Branwyn is editor-in-chief of makezine.com.

William Gurstelle is a contributing editor of MAKE.

Brian Jepson is an O'Reilly Media editor and hacker.

Tim Lillis is a freelance illustrator and DIYer.

Brookelynn Morris is the author of *Feltique*, a book about felt-making.

Meara O'Reilly (mearaoreilly.com) is a sound designer.

John Edgar Park is a frequent contributor to makezine.com.

Nick Raymond is one of MAKE's awesome engineering interns.

L. Abraham Smith works with open source hardware every chance he gets.

***** 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.

ELECTRONICS: FUN AND FUNDAMENTALS
By Charles Platt, Author of *Make: Electronics*

Electronic Rock-Paper-Scissors

Emulate the classic game using switches and LEDs.

IS IT POSSIBLE TO BUILD A FUN-TO-PLAY electronic game that uses only switches and LEDs, and no other components at all? Most definitely! The game I have in mind is an emulation of rock-paper-scissors — which has some strategic subtleties that may surprise you.

First I'll recap the rules, just in case you are one of the 3 or 4 people in the world who've never played this game. Two opponents face each other, and on a count of 3, each of them makes a fist to represent a rock, or displays a flat hand to represent paper, or shows 2 fingers to indicate scissors. Three rules determine the winner: rock blunts scissors, scissors cuts paper, paper wraps rock.

This sounds like a process of pure chance, but it isn't. The reason is that we are influenced by our human memories.

Consider an inanimate object, such as a coin spinning through the air. Because a coin has no memory, it doesn't change its current behavior based on its behavior in the past. If you throw heads a dozen times in a row, the coin is unaware of this history, and the odds of heads coming up yet again on the next throw remain exactly the same as before.

Human beings are different. We remember what we've done and tend to avoid repeating ourselves when we're trying to be unpredictably random. In a rock-paper-scissors session, this means that if your opponent makes a rock on 3 consecutive turns, he's more likely to try scissors or paper. If you anticipate this by making scissors yourself, you'll either tie or win. Either way, you reduce your chance of losing.

The problem is, if you're playing against an experienced opponent, he may realize

MATERIALS

LEDs with series resistor built in (8) Do not use a substitute. Part #LED-12R, LED-12W, or LED-12B (red, white, or blue — your choice) from allelectronics.com.

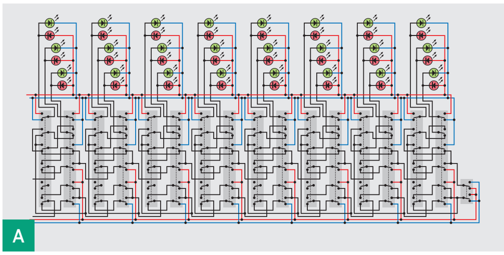
Switches, four-pole, double-throw momentary pushbutton (6) Part #612-PBMTH4UOANAGX from mouser.com. Caps sold separately: part #612-1C-GR.

For optional enhancements:

Beeper or buzzer, 12V e.g. Mouser #254-PB511-ROX

9V battery

9V battery snap connector



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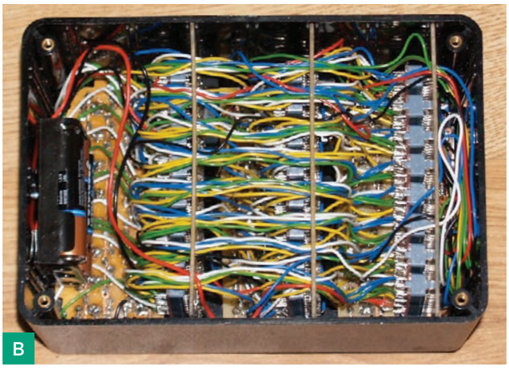


B

Fig. A: Switches and wires can emulate many operations in digital computing. This circuit adds two 8-bit numbers. Each green LED indicates a 1, while each red LED indicates a 0.

Fig. B: The wiring for the schematic in Figure A.

Charles Platt

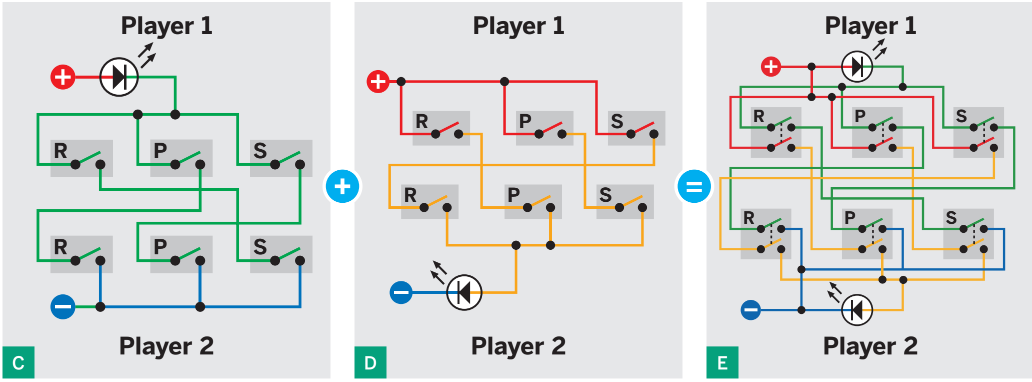


Fig. C: This circuit lights the LED in response to the 3 switch combinations that represent a win for Player 1.

Fig. D: The LED in this circuit lights in response to any of the winning switch combinations for Player 2.

Fig. E: The circuits in Figures C and D are combined using double-pole switches to create a minimal rock-paper-scissors game.

that you won't expect him to repeat himself. Consequently, he may repeat himself just to defy your expectations.

What if you know him well enough to expect this? Once again, you can anticipate his behavior and modify your strategy accordingly — but if he picks up on that, he'll modify his. This recursive process in which people try to second-guess each other is a common theme in the fascinating field of game theory, a branch of mathematics that became so influential after its invention in the 1940s, it even affected nuclear weapon strategies during the Cold War.

If we emulate rock-paper-scissors using switches and wire, this leads us into another interesting area: the fundamentals of computing. The evolution of digital computers began with telephone switching systems, and many of the low-level processes inside a computer can still be modeled using real switches.

Figure A shows an unusual example: a circuit that adds two 8-bit numbers using an array of 6-pole switches. It was designed by Graham Rogers, a British computer scientist in England, who has placed a Java applet showing how it works at henleymob.co.uk/Circuit/circuit.html. Figure B shows the actual device. Fortunately, our rock-paper-scissors circuit will be less complex than this — initially, at least.

→ START

Schematics

Figure C shows 3 switches to be controlled by Player 1, and 3 similar switches for Player 2. Each player presses a switch to indicate his choice of rock, paper, or scissors (indicated on the schematic by letters R, P, and S).

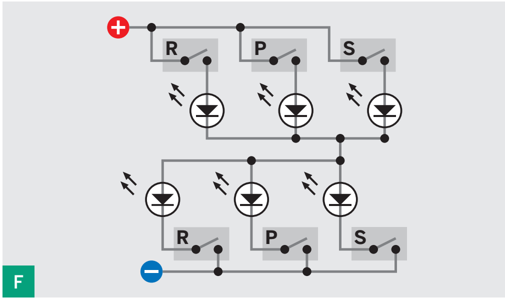
The connections are colored to make them easily distinguishable in subsequent schematics. Think of the colors as being like colored insulation on the wires.

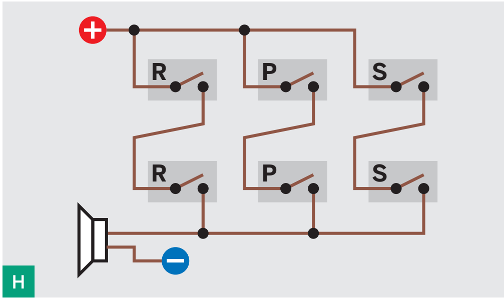
Study the circuit, and you'll see that when 2 switches sharing a green path are closed, they light Player 1's LED. The switches are wired in series, so they must both be closed to establish the outcome of the game. But each pair is wired in parallel, so any pair will light the LED.

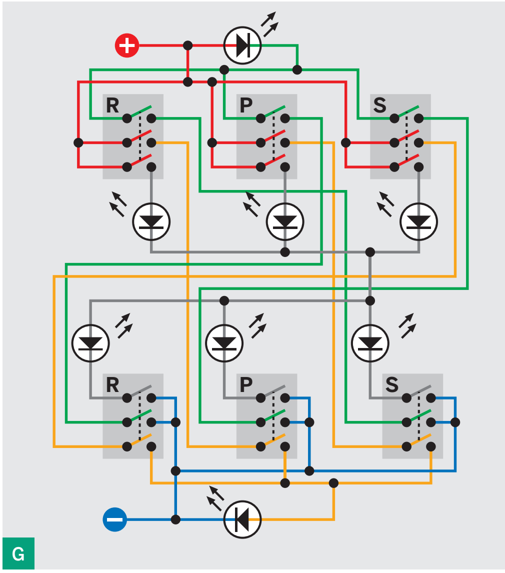
Each of the switch pairs will win the game for Player 1, while other combinations do nothing. Now check Figure D, which shows the 3 winning switch combinations for Player 2.

We can merge the 2 schematics by using double-pole switches, as in Figure E. One LED or the other will light up to identify the winner. If both players make the same choice, nothing happens. This is a complete emulation of the game, but we can add a lot more details.

To prevent cheating, the players should be unable to see each other's switches. But when the players have both pressed their switches, their choices should be shown by LEDs. We need 3 LEDs to show which of the 3 switches Player 1 has closed, and 3 LEDs for Player 2. However, these LEDs should not light up until both players have committed themselves. How can this be done?







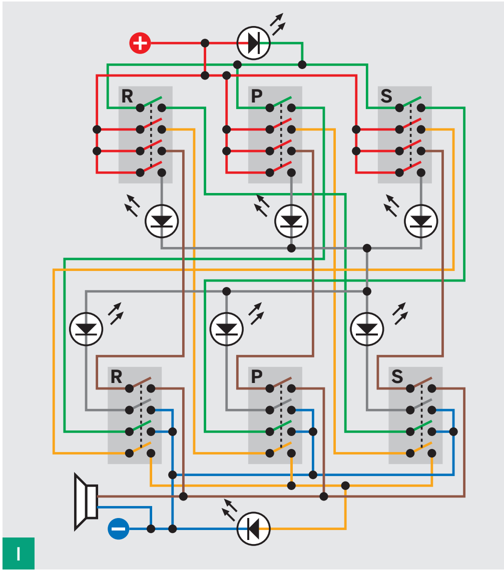


Fig. F: How to wire 6 LEDs to show which switches have been pressed.

Fig. G: The LED circuit is now embedded in the main schematic.

Fig. H: Additional wiring sounds a "tied game" beeper.

Fig. I: The beeper wiring is added to the main schematic.

Figure F shows the simplest circuit. By wiring the 2 groups of LEDs in series, we guarantee that Player 1's choice won't become visible until Player 2 also makes a choice, because that's the only way to complete the circuit. It is absolutely nonstandard practice to wire LEDs in series, but they will work if you use special LEDs containing their own resistors, specified in the parts list.

Figure G shows the player LEDs merged into the main schematic, using 3-pole switches. But wait, there's more. Figure H shows another enhancement to the game: a noisemaking device which sounds when the game is a tie because both players have made the same choice. Figure I shows this feature added to the main schematic.

If you build this circuit using 4-pole push-button switches of the type recommended in the parts list, you'll find they are double-throw switches. In other words, they have contacts that are normally closed, as well as contacts that are normally open. Figures that show the functions of the pins and how the switches can actually be wired together, along with game enhancements (such as a score counter and a way to prevent each player from cheating by pressing more than one switch at a time) can be found at makezine.com/28/electronics.

Make: Electronics book at the Maker Shed: makezine.com/go/makeelectronics

Charles Platt is the author of *Make: Electronics*, an introductory guide for all ages. A contributing editor of MAKE, he designs and builds medical equipment prototypes in Arizona.

1+2+3 Sneaky UV Ink Password Protector

By Cy Tymony

You can make it!

WITH SO MANY COMPUTER PASSWORDS to remember these days, it's necessary to safely store them somewhere — but not in a computer file. So where?

Write them with an ultraviolet (UV) invisible ink pen so the information can't be seen by the naked eye. Only shining a special UV light on the passwords will reveal them. Use paper with written material already on it, so people think the visible words are all that's there.

But how do you prevent someone else from using your UV light? By hiding it too! Here are 3 ways to render your UV light unusable to the casual snooper.

1. Hide a coin cell battery and UV LED.

Get a UV LED (available online for under $1) and a small watch battery (you could remove them from a standard UV LED light set). Wrap them together with tape, and hide them inside a wide-barrel pen. If needed, you can retrieve the parts, squeeze the battery between the LED's legs, and check your passwords.

2. Install a UV LED in an LED pocket light.

Use a screwdriver to open an LED pocket light. Remove the standard LED and replace it with a UV LED. Now shine the invisible beam at your message to reveal it. This method works well, but someone might be suspicious that you keep a "nonworking" LED pocket light around.

3. Hide your UV LED in a remote control.

To be really sneaky, substitute a UV LED for the infrared LED found in a TV or DVD remote control. Use a discarded remote, or buy a universal remote from a dollar store. If people try to use the remote, they probably won't detect anything unusual, because a remote doesn't make a bright light anyway!

YOU WILL NEED

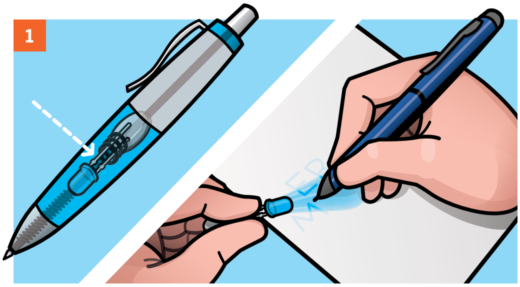
Invisible ink (UV) marking pen
UV LED
Paper

Option 1:
Wide barrel pen
Coin cell battery
Tape

Option 2:
LED pocket light
Screwdriver

Option 3:
Spare remote control

1



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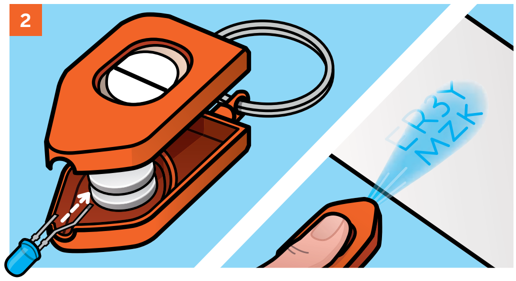

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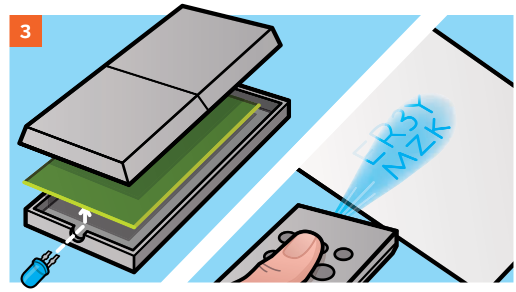


Damien Scogin

Cy Tymony is the author of the *Sneaky Uses for Everyday Things* book series. He lives in Los Angeles. sneakyuses.com

REMAKING HISTORY
By William Gurstelle, Workshop Warrior

Archimedes and the Water Screw

Re-create the invention that quenched the Egyptian desert.

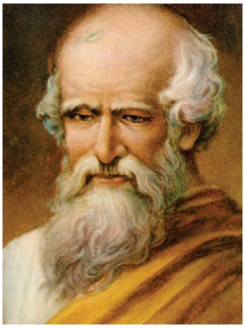
WHILE STUDYING AT THE LIBRARY OF Alexandria, Archimedes, the great mathematician of Syracuse, invented the worm screw, a simple but effective device that provided Egypt with a better way to grow crops. By dipping one end of the machine into a river or stream and rotating its auger-like conveyor, Nile Delta farmers could irrigate large tracts of otherwise arid farmland.

The Archimedean screw was a technological breakthrough in the third century B.C. Historical records show the device was soon adapted throughout the ancient world and put to use removing water from the bilges of ships and pumping water and sand out of mines.

The ancient open-pit mines along the Rio Tinto in southwestern Spain were perhaps the largest of the classical world. Roman historian and naturalist Pliny the Elder wrote that near these silver and lead mines, "The mountain has been excavated for a distance of 1,500 paces, and along this distance there are water-carriers standing by torchlight night and day steadily bailing the water (thus) making quite a river."

The miners of the Rio Tinto made intense use of Archimedes' screws. The Greek historian Diodorus Siculus reported that, "By these, with constant pumping by turns, they throw up the water to the mouth of the pit and thus drain the mine; for this engine is so ingeniously contrived that a vast quantity of water is strangely and with little labor cast out."

Today Archimedes' screws are everywhere. They transport liquids in sewage treatment plants, fish hatcheries, and farmlands; they move solids in coal mines, grain elevators,



HEAVY LIFTING

Archimedes of Syracuse (ca. 287 B.C. – ca. 212 B.C.), Greek mathematician and engineer, not only discovered the principle of buoyancy, the law of the lever, and the formula for the volume of a sphere, he also battled Roman ships with solar death rays and invented the water screw that irrigates farmlands to this day.

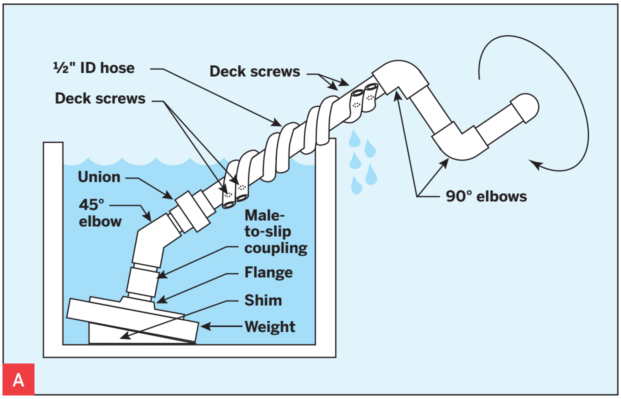
Getty

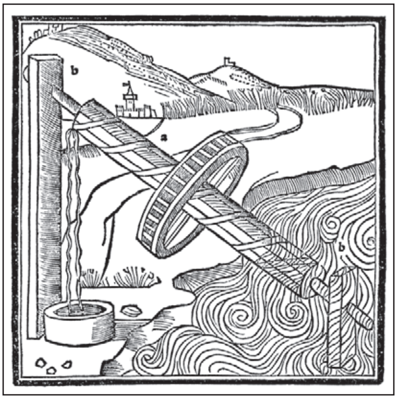
snow blowers, and a host of other devices.

At first glance, the manner in which the Archimedean screw works is something of a mystery. Why does turning the crank cause water to rise? The best way to understand it is to imagine placing a small ball in the screw-auger mouth at the bottom of the device. The ball rests in the depression defined by the curve of the screw. As the crank is turned, the instantaneous location of the ball-holding depression moves up the centerline of the screw, and likewise, up moves the ball.

Calculating the volume of water moved by a turn of the screw requires the manipulation of many different parameters, including the radius and angle of the screw, the ratio of the screw's outer and inner cylinders, and the pitch of the blades. Further, constructing the screw in the manner of the ancients is quite difficult, requiring a great number of exacting operations.

Luckily for us, we 21st-century types can re-create Archimedes' invention using inexpensive plastic tubing. Building a model screw pump this way is quick and simple and has the advantage of being easy to reconfigure, so





MATERIALS

Plastic or rubber hose, ½" ID, 32" lengths (1–4)
PVC pipe, 1" diameter, 38½" total length cut to lengths of 22" (1), 6" (2), and 1½" (2)
PVC pipe fittings, 1" diameter: 90° elbows (2), cap (1), union (1), 45° elbow (1), NPT male-to-slip coupling (1)
PVC cement
Flange, iron, 1" opening, threaded
Flat, heavy weight such as a barbell plate
Shim, 15°
Deck screws, 1⅝"

TOOLS

Screwdriver to match your deck screws
Scissors

many experiments are possible.

Here's how to build a pump that works on the same principle as Archimedes' original screw — a coiled passage that rotates to move pools of water progressively upward.

.

→ START

1. Fasten one end of the hose to the bottom end of the 22" PVC incline tube using a deck screw. Screw through the hose's inner wall only (the wall touching the PVC pipe) — you want its mouth to remain open and unobstructed.

Wrap the hose around the incline tube using a 4 to 1 pitch (see Figure A) and fasten the upper end to the incline tube with another deck screw in the same fashion. Cut off excess tubing with scissors.

2. If desired, you can increase the volume of water moved by adding a second, third, or even fourth hose to the incline tube next to the first. Just wrap and fasten each hose to the incline tube as described.

3. Build a base for the screw pump. Assemble the 45° elbow as shown in the diagram: on one side a 1½"-long pipe and the pipe union (not screwed too tightly); on the other side, another 1½"-long pipe, the NPT male-to-slip coupling, the flange, and the weight. The coupling and flange are screwed together (no glue is necessary), and you may have to improvise a bit to attach the flange to the weight.

Cement the pipe fittings and place a 15° shim under the flange so the screw is held at an angle about 30° from horizontal.

4. Build a crank for the screw using two 6" lengths of pipe, 2 elbow fittings, and a cap.

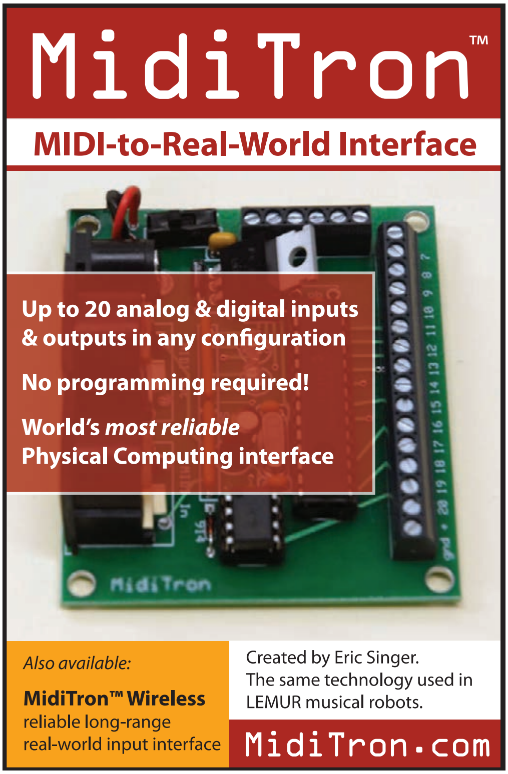
5. To operate the screw pump, place its base in water. Turn the crank so that as the screw rotates, the open end of the tubing scoops up water. With each subsequent turn, the scoop of water will rise one pitch length up the screw shaft, finally emptying out at the top.

6. Experiment with different angles, pitch lengths, crank speeds, and tube quantities and diameters to see how efficient you can make your Archimedean screw pump.

+ See also: "The Turn of the Screw: Optimal Design of an Archimedes Screw," by Chris Rorres, at makezine.com/go/archimedes.

MAKE contributing editor William Gurstelle wrote the "Gravity Catapult" project on page 84. He is the author of DIY books including *Backyard Ballistics* and *The Practical Pyromaniac*.

Gerry Arrington (A)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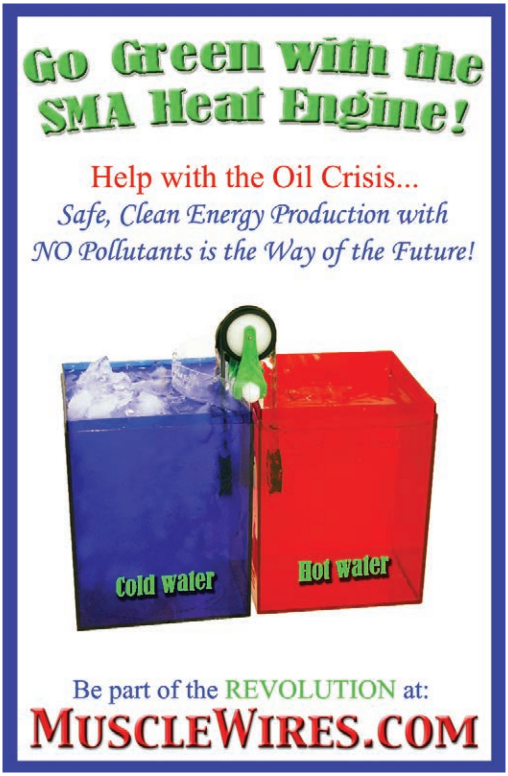
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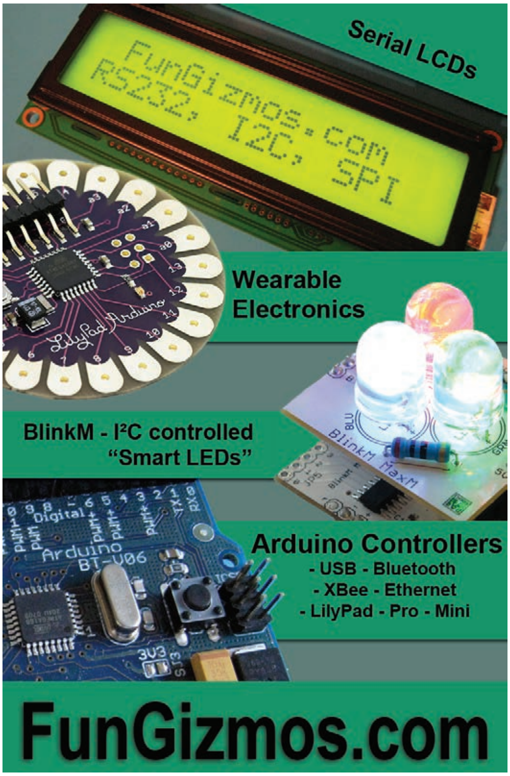
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HOMEBREW

My Home-Built Chairlift

By Jeff Johnson

+ Check out Jeff's full how-to at makeprojects.com/project/h/917

MY LOVELY WIFE AND I BUILT A BEAUTIFUL house next to a lake, but we had no easy way to get down to our dock. Friends and neighbors joked that we needed to build a chairlift; we all laughed. Then at some point the laughs became musings, musings became a plan, and six months later, we had our own lift.

We basically built a rolling cart that rides along 3-inch, Schedule 40 pipe and is lowered and raised via two drums that are each attached to 7,000lb-capacity aircraft cable. (We doubled the line in case one breaks.) A variable-frequency drive motor controls the drums. The motor controller takes single-phase 220V power and converts it to three-phase variable frequency for speed control.

A Linear brand four-button remote sends signals from the cart up to the main control unit. The pipes themselves double as conduit to get our control lines down to the lower box that lets us send the cart back down, and they allow me to run power lines down to my dock.

For a while, the cart wouldn't stop fast enough at the bottom when overloaded. After some research, we finally discovered that the motor controller would only allow so much back current. We reconfigured the controller to override the protection parameter and provided a power resistor the size of a tennis ball can to absorb the excess power. At $80, it's the most expensive resistor I've ever bought.

My dad and I built the chairlift as a team, and it was a very fulfilling life experience, both as a functional, useful project and as a father-son endeavor. As I was draining our bank account and my vacation time building it, my wife kept calling it "your tram!" Once it was finally done and worked, she started showing it off to her friends and family, talking about "our tram." Good thing she couldn't hear my eyes roll. We both laugh about that now.

Jeff Johnson is the grandson of two Manhattan Project engineers and the son of an engineer. A programmer, he gets his tech fix at local hackerspace LVL1. He lives in Louisville, Ky.

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ELECTRONICS

Make: Electronics Suite

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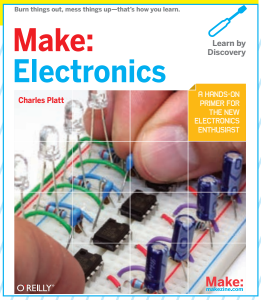

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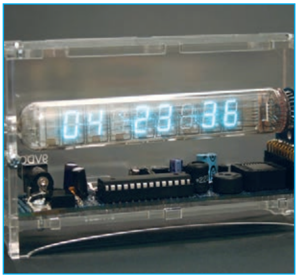

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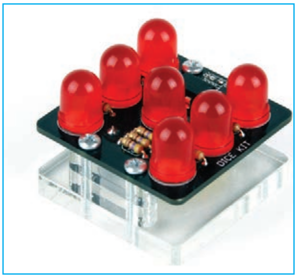

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MICROCONTROLLERS

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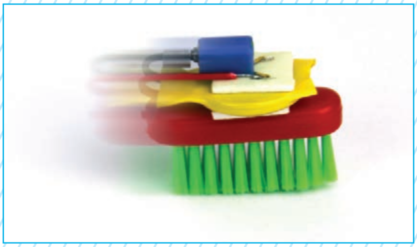

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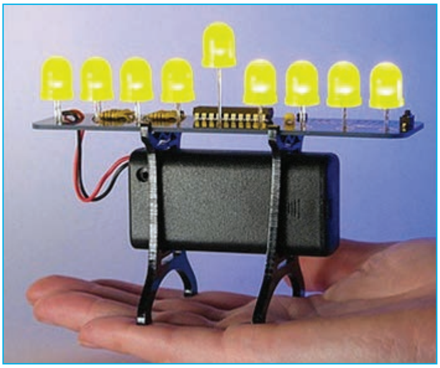

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