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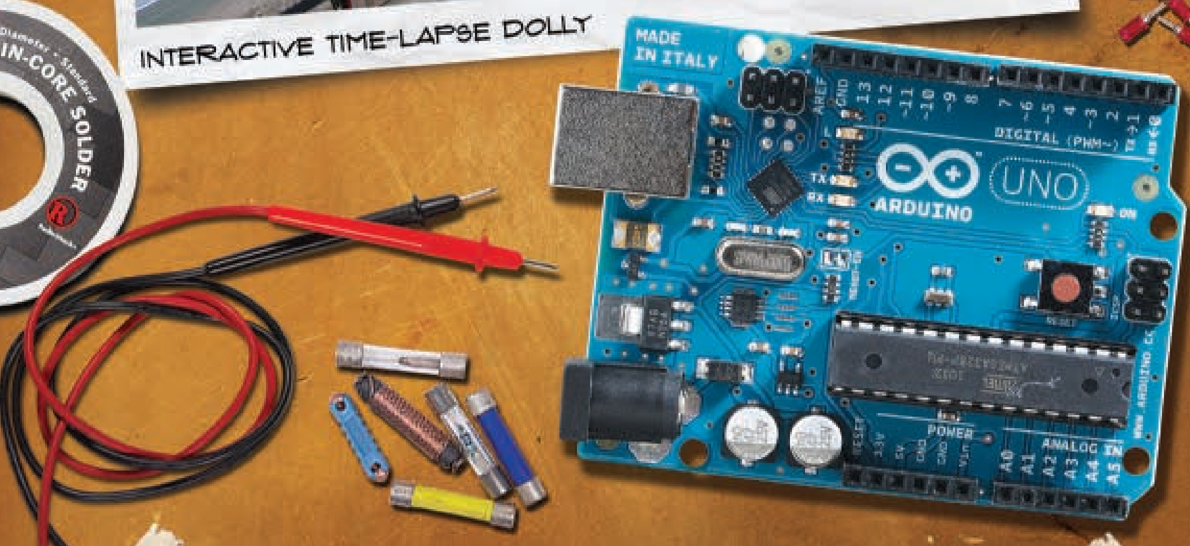

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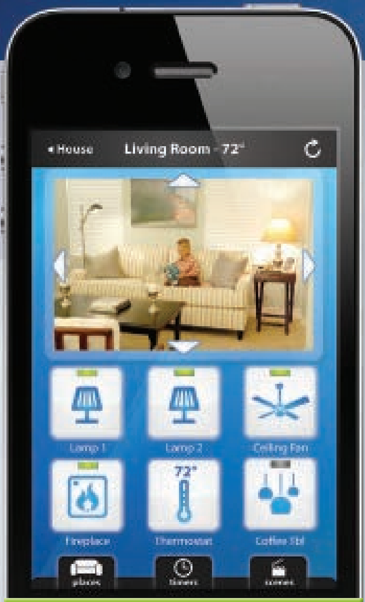

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Make: Volume 30

SMARTER HOMES

Columns

SNAPPY "TOWEL": It's the powerful, highly maneuverable R/C flying wing that's easy to make, fly, and fix. Photography by Gregory Hayes. Art direction by Jason Babler. Plane built by Daniel Spangler.

I SPY: Build a 4-webcam video switching system, and see who's playing while you're away.

KEYBANGER'S BALL: Program any electrical device with pushbuttons, without writing a line of code.

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"It's just a smart thing … brilliant."
— **Becky Worley, ABC's Good Morning America**

"The next best home upgrade for your digital family."
— **Casey Tschida, AppAdvice**

"I love it … you can plug in your phone and your tablet along with your toaster oven and coffee maker … Nice."
— **Lori Cunningham, The Well Connected Mom**

"… my 2011 gadget of the year is the Newer Technology Power2U."
— **Gregg Ellman, Miami Herald**

"… I will be getting plenty of use out of the...Power2U … with my whole family using more electronic devices than I care to count."
— **Thomas Ratas, Test Freaks**

"I can't think of anything more convenient when you're wanting to charge your iPhone."
— **Mike Ferrara, TechnoDad.tv**

"… we love the Power2U … a great product … makes the lives of anyone with multiple electronics a little easier … without the need of any adapters."
— **Nathan Kirsch, Legit Reviews**

"… a must-have device for the home of today."
— **Kristofer Brozio, DragonSteelMods**

"Very clever … an outlet with … two plugs, two USB ports … when it closes, shuts off phantom power."
— **Dick DeBartolo, The Giz Wiz**

"I'm … a huge fan of the Power2U … a great accessory for anyone with multiple gadgets to charge … easy enough for anyone to install."
— **Josh Smith, Gotta Be Mobile**

Upgrade your home to integrate your digital life

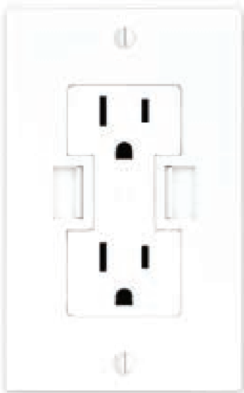
Turn your walls into USB charging stations with the Newer Technology Power2U™

It's the twenty-first century and electronics fill the pockets of teens and adults in every home. Phones, GPS devices, iPads—all kinds of devices, and the majority of those charge via USB.

You typically have two options for charging these devices:

- Plug directly into the computer for USB charging
- Use a USB power converter that plugs into the wall

Power2U gives you another option—remove power adapter clutter and make USB charging more convenient. Turn your walls into charging stations by installing native USB outlets directly into the wall with Power2U.



Basic DIY Install

- Installs on standard 15A electrical circuit
- Smart Power outputs only as much power as required to charge connected devices
- Safety Shutters turn off USB power when closed to eliminate "vampire" draw
- How-to videos available online

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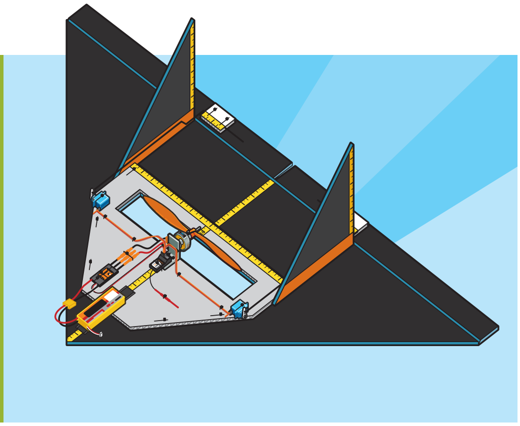
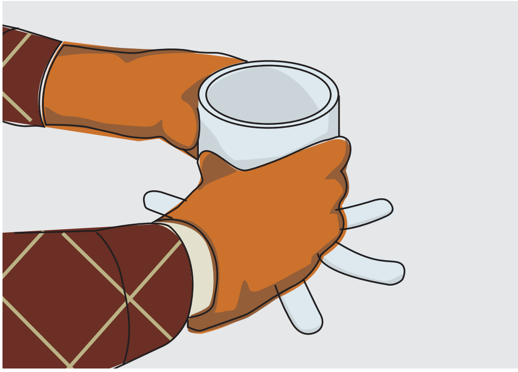
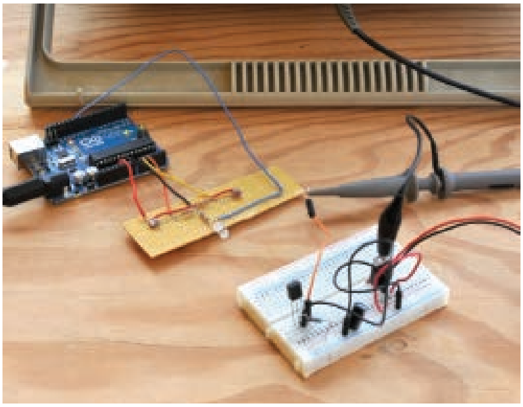
Make: Projects





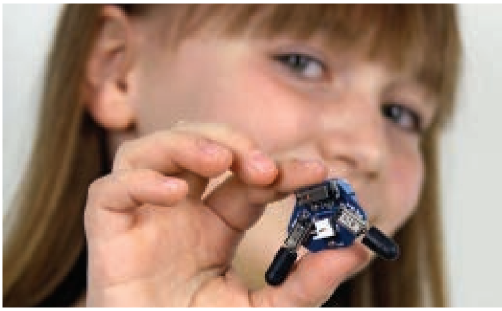


Make: Volume 30

Maker

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

HIGH-TECH HOBBITRY: Filmmakers and friends build their Shire in the Santa Cruz Mountains.



DIY

SIGNS POINT TO YES: Build an electronic, random fortune-teller inspired by the classic toy.


You say delicious, we say ballistic.
Get our newest kit, the marshmallow shooter.
Make:
makershed.com/marshmallow

"To invent, you need a good imagination and a pile of junk."
—Thomas Edison

Make:

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CONTRIBUTORS

Breck Baldwin (*"The Towel" R/C Flying Wing*) is the founder of LingPipe, whose offices are perched at the edge of McCarren Park in Brooklyn, N.Y. He steadfastly denies that the office was chosen for the excellent flying site only steps away. The Brooklyn Aerodrome R/C plane collective grew out of a desire to introduce UFO awe in the night sky to jaded urbanites. The project has morphed into a teaching tool, DIY object of fascination, and art entity that is collectively developed by a loose group of innovators. He developed the Towel as a healing intervention for all the unfinished, unflown, or crushed balsa plane dreams of children everywhere.

Dan Spangler (MAKE engineering intern) describes himself as "a big, fuzzy, fun-loving guy who has an amazing knack for making things." He has a penchant for building projects that explode. "I made my first combustion spud gun and promptly shot out the window of my dad's truck, which was parked across the street," he laughs. He is currently working on a number of exciting projects, including a jet engine Tesla coil, a rocket engine, a Gatling gun, a model internal combustion engine, a giant piloted Maker Faire robot, and a nuclear fusion reactor.

Jessica Fortner (*Yakitori Grill* illustration) is an illustrator from Toronto, Ontario, focusing on editorial, advertising, and children's illustration. Jessica's work has appeared in publications such as *Juxtapoz*, *The New York Times*, *Ammo Magazine*, *Digital Arts*, and *Pork & Mead*. Also, her portfolio website has been featured as one of *How*'s Top 10 Sites for Designers. She is co-founder, editor, and designer of the online arts magazine *Squidface & The Meddler* (squidfaceandthemeddler.com), and founder of the arts site Tangled Fingers (tangledfingers.com). A design enthusiast, she's particularly fond of sustainable design, interface design, and typography.

Tom Lauwers (*IR Remote Hacking*) is the founder of BirdBrain Technologies LLC, maker of the Finch robot, Hummingbird robotics kit, and the Brainlink universal robot controller. According to the Carnegie Mellon Robotics Institute, Tom is both a master and doctor of robots; he is an invaluable ally in the event of a robot uprising. Born in Belgium and raised in Silicon Valley, he now resides happily in Pittsburgh, Pa., with his wife, two kids, and a small army of robots. This brief bio contains variations of the word "robot" eight times, which tells you much about Tom's current preoccupation.

George Tempesta (*Notification Alert Generator*) is the proud but forgetful father of three beautiful daughters. The NAG is actually his wife Traci's brilliant idea to prolong their marriage! George has been tinkering with and fixing things most of his life, and has an insatiable appetite to know how things work. When he's not messing around with electronics or fixing one of his cars, he can be found camping, boating, or fishing with his family. His kids have inspired him with their amazement at the things he makes.

Eric Merrill (*Cellphone Car Ignition* and *Networked Smart Thermostat*) is a programmer by trade and photographer by hobby. He has had a passion for electronics and robotics since taking three years of classes on the subject at a technical center in high school. Married with his first child on the way, he is now a member and current CEO of the i3 Detroit hackerspace (i3detroit.com). In addition to various automation and electronics projects, he enjoys working on his quadcopter and learning to use the equipment at i3.

WELCOME

By Mark Frauenfelder

George Jetson's Wild Ride

***THE JETSONS* WAS AN ANIMATED PRIME-**time sitcom that debuted in 1962 as a time-warp twist on Hanna-Barbera's previous hit, *The Flintstones*. *The Jetsons* depicted family life in the year 2062. One of the reasons I loved the show was the futuristic technology it featured in every episode.

The show's end title sequence has an exemplary roundup of Jetsonian-age conveniences. The scene opens with George Jetson gliding home to the Sky Pad Apartments in Orbit City. As George slides through the front door on a moving sidewalk, Rosie, a robot housekeeper dressed in a maid's outfit, greets him and takes his briefcase.

A second later, a molded fiberglass chair springs out of a hidden door in the sliding walk and smartly scoops George right out of his white plastic boots. George falls into the chair, nearly supine. He smiles and shuts his eyes. The chair whisks George to his boy Elroy, who slaps a pair of slippers on his father's feet, then onward to daughter Judy, who lovingly puts a pipe in his mouth and kisses him on the cheek before the chair conveys him away.

George's chair ride ends where Jane, his wife, and the family dog, Astro, await him. Jane gives him a kiss as she hands him Astro's leash, and the Goliath-sized dog bounds outside, dragging an alarmed George along.

The scene cuts to a conveyor treadmill outside the apartment's back door. George is walking the dog when a cat hops onto the belt. Astro gives chase and the belt spins out of control, with George sprinting wildly to keep up. The dog and cat hop off and enjoy the spectacle of George, trapped on the belt, crying, "Help! Help! Jane, stop this crazy thing!"

In a way, the scene tells the same lesson told in the movie *WALL-E*, in which people of the future have ceded their body movement to automation. They ride in floating scooters with extra-large cup holders for the sugary drinks they consume around the clock. The lesson is that technology specifically designed to allow you to sit and do nothing is not without consequences. (Does a TV remote control cater to short attention spans, or create them?)

MAKE's special section this issue is about Home Automation, and we didn't take the subject sitting down. In fact, we went in the opposite direction. Instead of a pushbutton haven for couch potatoes, we imagined a networked space for active makers who want to efficiently manage the systems in their homes from anywhere they might find themselves — whether they're in the kitchen, out in the backyard, or on the other side of the planet.

New wireless protocols and cellphone-based interfaces make it easier than ever to control your castle. We've got projects that show you how to flip any switch in your home from your mobile phone (*page 66*) or even start your car (page 136), how to receive timely verbal reminders to do household chores (*page 50*), and how to program home systems without writing a line of code (*page 72*). You'll learn how to set up a webcam security system (*page 44*), give classic X10 automation modules a new brain (*page 60*), make an Arduino-controlled thermostat that'll cut your energy bill and take commands over the internet (*page 54*), and more.

Other projects in this issue are sure to keep you out of your chair, too, like the yakitori grill (*page 108*), our new Supercap Racer toy kit (*page 126*), and a radio-controlled flying wing that's easy to make and incredibly fun to fly (*page 82*).

So, get automated and get active!

Mark Frauenfelder is editor-in-chief of MAKE.

READER INPUT

From Makers Like You

Soapy Peril, Nerf Newbies, and Real-Life Heroes

I read Saul Griffith's column in Volume 29 ["MENTORing Kids into Makers"] and I was just so impressed at your undertaking. I'm sure MAKE's new Makerspace program (makerspace.com) will change student's attitudes toward STEM. You might be interested in the Lemelson-MIT poll of 16- to 25-year-olds. *Popular Mechanics* reports that "Nearly a third said they had little to no experience building anything hands-on, whether it's a digital product like a website or a physical project like piecing together a circuit."

I also really like that you've put role models on the cover of the magazine. Having a role model, especially one that's not your stereotypical white male, can help young students picture themselves in a STEM profession. In a program at Techbridge, an organization dedicated to expanding the options of girls interested technology and engineering (I'm a board member), we found that without role models and field trips to worksites, students saw hands-on activities as a hobby but not a career.

I strongly encourage the Makerspace program to incorporate role models. I also encourage MAKE readers to become role models to their children, nieces, nephews, or friends' children.

—Lyn Gomes, PE, LEED AP, mechanical engineer, and maker (Motorized Barcalounger), Livermore, Calif.

Thank you for featuring real-life superhero Carol Reiley [MAKE Volume 29, "Air Guitar Hero" and "DIY Blood Pressure Monitor"]. She's just as smart as Tony Stark and more attractive than Wonder Woman, and on top of that, she builds robots that save people. Reiley is a true inspiration.

—Bob Bohan, Kent, Wash.

Garry McLeod (Carol Reiley)

I picked up the MAKE: Ultimate Kit Guide 2012 (kits.makezine.com), and after gleefully devouring its packed pages, I want to thank your team for putting together such a wonderful collection of kits. What I appreciate most is the distilled simplicity of it. The personal commentary of your reviewers cuts through the hype and/or lack of information associated with many kits, and gets to the heart of what I'm interested in. Thanks again for going the extra mile.

—Aaron Stone, Fort Worth, Texas

As a science teacher and Ph.D. chemist, the soap-making tutorial in Volume 29 ["Making Bar Soap"] caught my eye for a few reasons. » None of the pictures illustrate the safety equipment that's specified.

- The exact proportions of oil and sodium hydroxide (NaOH) are extremely important for safety reasons. Excess NaOH can remain, and the pH of the soap is not tested. When you get NaOH on your skin, it feels soapy (it's actually making soap from the fatty acids in your skin); this is worth explaining so people know they might have got some on them.
- It's true that the amount of NaOH used in your method should not be enough to react with the all of the oil completely; this is itself a safety precaution, because in theory all the NaOH will be used up. But the type of oils used shouldn't be changed, as this would alter the amount of NaOH required.
- Any mistakes made during this process are much more serious than any "toxins" found in off-the-shelf soap.

—Zac Watts, Melbourne, Australia

I'm not impressed with the homemade Nerf blaster in Volume 29 ["Better Nerf Gun"]. There's an online community that has tackled this problem in ways that are far easier. Not every maker has a lathe, and using metal racks up the cost and difficulty. A better blaster can be built for $20 out of PVC pipe and fittings by a newbie with a Dremel, and gets ranges of 60ft to 80ft. Heck, even a well-made HAMP (High Airflow Manual Plunger) gets 60ft, and it uses yarn for the seal! I'm disappointed that the novice maker was ignored.

—Daniel Seyler, Pocahontas, Illinois

EXECUTIVE EDITOR PAUL SPINRAD REPLIES: Thank you for writing. I think our Nerf gun is beautiful, but it does require metal lathing, wood shaping, and other operations that aren't quick or easy. Is there a quick PVC Nerf blaster or HAMP you'd recommend? An easily built high-performance PVC Nerf dart blaster sounds really fun.

DANIEL SEYLER REPLIES: The HAMP is one of *the* most basic NERF guns, originally documented on NerfHaven (nerfhaven.com) by member KaneTheMediocre. You can build one for $10 in less than an hour!

I own a toy store and have been pushing the educational power of toys for decades [Volume 28, "A Curriculum of Toys"].

"Toy learning" is very right-brained, all about patterns and relationships. Most classroom learning is left-brained, all about labels and logic and rules. There are schools that are finally realizing just how much of the right brain we leave untapped in our schooling process (other than fine-arts programs), and are now starting to incorporate more discovery into regular academics.

Neurologists are also beginning to see how previously labeled "disabled or difficult learners" are often right-brained children in a left-brained school. Exercises (both mental and physical) designed to help reconnect the right and left hemispheres are proving successful in helping these kids adapt better to school.

—Phil Wrzesinski, Jackson, Mich.

It is just my opinion but your magazine is the best magazine out there. When I read the Robots issue (Volume 27) I really wanted to build those robots and possibly merge them. In the Toys and Games issue (Volume 28) I wanted to build the catapult really bad. The instructions for the projects are good at telling me what to do, and you seem to include the blueprints that I need to build a device right away. Thank you for publishing such an awesome magazine.

—Anthony Rinaldo

MAKE AMENDS

Volume 29's Country Scientist column stated that "Water vapor ... alone keeps the Earth warm enough to prevent the entire planet from freezing." In fact, while water vapor is the gas most responsible for the greenhouse effect, it is not sufficient to prevent "snowball Earth" conditions — that requires CO_2 as well.

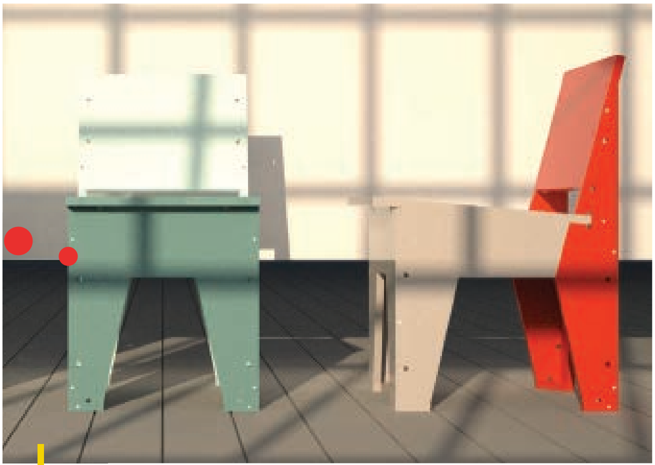
Also, we may have implied that air temperatures decrease with altitude because the air is dryer, when the opposite is true: the air is cooler at altitude because of lower pressure, and it's dryer because cooler air holds less vapor.

Thanks to reader Christopher Hogan for spotting the errors, and to Dr. Gavin Schmidt of the NASA/Goddard Institute for Space Studies for setting the record straight.

In the schematic for Volume 26's "Luna Mod" sound looper, the labels for Tempo and Sound were mistakenly reversed. The corrected schematic is online at makezine.com/26/lunamod and makeprojects.com/project/t/974.

Got an idea?

100kGarages connects you with people who can turn your thoughts into things.



Anne Filson and Gary Rohrbacher have created designs for beautiful, functional furniture (called AtFAB) that customers can fab themselves or have made for them using a ShopBot or other CNC tool. To prototype and make the pieces ready-to-fab, they connected with Jeff Shapiro through 100kGarages, and have been collaborating for the past two years. Says Anne, *"We've become friends as fellow makers. That's been central to our success."*

Get it made.

Got a CAD design file, or just a napkin drawing?
We have free resources to help you get your dream project made.

Want some help from a designer?
Post your project on **100kGarages.com** for designers to bid on.

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MAKER'S CALENDAR

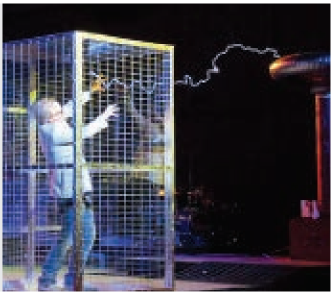
Compiled by William Gurstelle

Our favorite events from around the world.

Maker Faire Bay Area

May 19–20, San Mateo, Calif.

The seventh annual Maker Faire Bay Area is guaranteed to be huge, the Greatest Show (and Tell) on Earth. This two-day family friendly Faire has something for everyone — it's a festival of invention, creativity, and resourcefulness, and a celebration of the maker movement. makerfaire.com



James Bastow

MAY

» Indianapolis 500 Emerging Tech Day

May 7, Indianapolis, Ind.

Some of the best and brightest young minds in America will show off their renewable technology ideas for the automotive industry here. A highlight is the competition at the Indianapolis Motor Speedway by alternative-power vehicles in the Formula Hybrid and American Solar Challenge series. makezine.com/go/emergingtech

» Lego Inside Tour

May 23–25, Billund, Denmark

The Lego factory opens its doors to the public in a rare open house. The two-and-a-half day tour includes an opportunity for hardcore Lego enthusiasts to meet the product's designers, tour the factory, and visit the archive. makezine.com/go/legotour

» Alumapalooza

May 29–June 3, Jackson Center, Ohio

Alumapalooza is a festival of all things Airstream, the oldest and perhaps best-known travel trailer. Highlights include a rare look at how trailers are manufactured inside the factory, customization work shops, and social activities. alumapalooza.com

JUNE

» Transit of Venus

June 5, Mishawaka, Ind.

Celebrate the 2012 transit of Venus across the face of the sun with a planetarium program, public lectures, and a performance of Sousa's "Transit of Venus March." Telescopes will be set up for public viewing, and the NASA Edge webcast will bring live coverage from Hawaii. transitofvenus.org/trove

» Northern Spark

June 9–10, Minneapolis, Minn.

Inspired by European nighttime art festivals, Northern Spark turns the Mississippi River into one giant art gallery. Last year there were more than 100 public art projects, including a sewer pipe/storm drain pipe organ installation and a bioluminescent plankton light show. 2012.northernspark.org

JULY

» Wisconsin Farm Technology Days

July 17–19, New London, Wis.

Each year, several Wisconsin family farms are selected to host this three-day event that showcases the latest innovations in agriculture. The approximately 600 educational and commercial exhibitors show off everything from arts and crafts and dairy equipment to heritage equipment and "beef exhibits." wifarmtechnologydays.com

✱ 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**.*

Coming soon to a summer near you.

Over 50 fun projects. Shot in enhanced 3D.

Summer just got a lot cooler.

Make:

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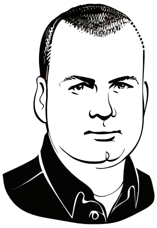


MAKING IT LEGAL

By Ryan P.C. Lawson, Esq., Small Business Advocate

What's in Your Toolbox?

IF YOU'RE A MAKER, YOU PROBABLY HAVE a toolbox. If you're a careful maker, you have some safety tools in that toolbox, like safety glasses and earplugs. Maybe you have rubber gloves if you work with chemicals. There's another safety tool that makers should have at their disposal: a company.

"Company" is a word that garage-based makers might not want to be associated with. It may bring to mind large, faceless corporations that care more about profits than innovation or creation. But the people who started these companies did it as a way to protect their owners and investors.

Just as you protect your eyes and hands with glasses and gloves, you protect your assets with a company. Companies give us the concept of *limited liability:* a company's owner is generally only liable for the amount that they invested in the company. This is an incredible protection, because no matter how careful you are, accidents happen.

Let's say you design and sell remote-controlled lawn mowers. What if RF interference causes the mower to go off course? Even if an accident isn't your fault, someone may be injured or even die. We live in a world where no one likes to take responsibility for their actions, so they may come looking for you because your name is on it.

If you've made a company, a customer generally has to go after the company. Of course, there are some exceptions to this and some rules you have to follow to make sure this happens. A company is a person under the law, and though you control it, it isn't you. That means the only thing someone can go after is what the company owns. So, while company-owned tools might be at risk, your house and your car may be protected.

Your company might be just you as the inventor, or you and some close friends who share an idea. If you have multiple people, the rules you set up on how you run your company can prevent arguments about how profits are shared, who gets to vote on important decisions, and how votes are counted.

There are lots of different kinds of companies, such as the traditional company, the LLC, and the S corp, and these vary depending on what state you live in. Forming a company isn't that hard. In most states, it just involves filing a form and paying a fee.

Just as you protect your eyes and hands with glasses and gloves, you protect your assets with a company.

While you're not required to get a lawyer, there are many reasons to have one help you get started. A short conversation with a lawyer will help guide you to the right type of corporation for your business. A good lawyer will explain your options and offer to let you save money by filling out the forms yourself and give you assistance if you need it.

A business lawyer can also explain rules you can set up internally to avoid future conflict. The lawyer will tell you how to prevent someone going around your company to try to get to you. Most importantly, by consulting a lawyer now, you'll establish a relationship with someone you can consult if something goes wrong or if you need some fast advice.

Protecting yourself with a company is the best legal safety tool you can have as a maker, and it should be in your toolbox.

Ryan Lawson is a Michigan lawyer. His practice focuses on technology licensing and advising small businesses.

Stick City

When **Scott Weaver** first started gluing toothpicks together to create sculptures at the age of 8, little did he know he would later embark on a monumental 34-year journey toward completion of his epic *Rolling Through the Bay* sculpture.

The fourth-generation San Franciscan started *Rolling Through the Bay* in 1974 as a smaller piece that featured his signature ping-pong ball path running through it. He continued to work on the piece off and on until 2008, when he debuted it at the Sonoma County Fair, winning Best of Show. Utilizing a staggering 100,000 toothpicks, it stands 9 feet tall, 7 feet wide, and 30 inches deep, and features four different ping-pong ball routes that start at entry points atop the piece and travel past San Francisco landmarks. Weaver uses only Elmer's white glue.

The ping-pong ball routes are essential for a full appreciation of the details, which are so numerous and uniform in color that they risk being overlooked. The main tour starts at Coit Tower, wraps under a Rice-A-Roni cable car, through the Transamerica Pyramid, out to the Cliff House, down Lombard Street to Chinatown, back toward the Palace of Fine Arts, out around the windmill at Ocean Beach, across the Golden Gate Bridge, over Humphrey the humpback whale, behind Alcatraz, by the Maritime Museum, ending in the long-lost Fleishhacker Pool.

At Maker Faire Bay Area 2011, Weaver earned Editor's Choice blue ribbons and had perhaps one of the most photographed projects at the Faire. He is fueled by seeing people's reactions to his work, recognizing the madness in his method. "What kind of eccentric idiot would spend thousands of hours making a toothpick sculpture? That's me!" *—Goli Mohammadi*

+ rollingthroughthebay.com

Luigi Anzivino/Exploratorium


ROLLING THROUGH THE BAY

On-Demand Rainbows

It's not obvious what the Rainbow Machine does at first glance. The machine's arm of colorful flashing LED patterns gives it the look of a carnival gate or a giant's wand. But a long-exposure photograph turns the motion of the machine's arm into a vibrant rainbow.

Reid Bingham and I (**Sean McIntyre**) debuted the Rainbow Machine as a light-painting photo booth at the outdoor light-art festival Bring to Light: Nuit Blanche New York. One after another, groups of friends posed for 10 seconds in front of the machine while the LED arm painted the rainbow behind them. With an initial flash, the group was crisply captured in the photograph.

The flash was also my cue to rotate the machine's flashing arm 180° in the air. The group blocked the LEDs traveling behind them, cutting out their silhouettes from the photograph's light-painted rainbow. Their rainbow photo immediately showed up on the on-site monitor.

By the end of the night, we accumulated 186 photos, all of which were uploaded to a Flickr account and given away for free.

A year prior to this debut, Reid and I met working on an art installation at a Brooklyn warehouse party. Inspired by light-painting projects and artist Alexander Kurlandsky's Robo-Rainbow (*see MAKE Volume 26, page 69*), we combined Reid's LED art with my programming background to create the Rainbow Machine. We wanted to build something that everyone could enjoy in a variety of settings.

Reid and I continue to upgrade the Rainbow Machine. A new feature translates JPEG images into complex patterns of blinking lights on the machine's arm. Our next challenge is automating the arm's movement.

—Sean McIntyre

+ therainbowmachine.com

Shameel Arafin

Sabine Marcelis

Refine Your Own Wine

While the art of making fine wine is usually left in the hands of seasoned winemakers in places like Napa or Bordeaux, it really doesn't have to be. Anyone who has seen the movie *Bottle Shock* knows that you never really know where the next great wine will hail from.

Thanks to Netherlands-based designer **Sabine Marcelis**, the next great winemaker could very well be you!

Marcelis got the inspiration for her do-it-yourself winemaking kit while in New Zealand, where "it is not so uncommon to brew your own wine at home," she writes. "While making a batch of apple wine and grape wine, I carefully observed and recorded all the steps needed to get it from fruit to bottle. I quickly discovered some key problems with the current techniques which make the process both messy and unappealing."

This all-in-one kit, called House Wine, was used for her graduation design project, and is as beautiful as it is easy to use. All of the equipment needed for nurturing the fermentation process, siphoning the wine, and bottling and corking is stored within the base of the unit. And the design is smart enough that it makes items such as funnels, bottle cleaners, and stirrers extraneous. Less equipment also means fewer things to sterilize and therefore less work.

She writes, "The [home brewing] process is often hidden away from view in garages and basements. This is a real shame, as wine is a living, breathing entity, which deserves an audience to witness it maturing."

House Wine celebrates the process of wine-making by bringing it into our living space. Best of all, House Wine potentially enables experimentation, creating a whole new world of blends. I'll drink to that.

—Jerry James Stone

+ sabinemarcelis.com/work/house-wine

Louis Lemaire

Mighty Mini Men of Metal

Amsterdam native **Mark Ho** was at film school, working in stop-motion animation, when he built his first articulated metal armature. That project sparked his imagination with visions of a kind of "ultimate puppet" — an intricately jointed, fully poseable figure with all the grace and range of movement of a real human body.

After graduating, he apprenticed in the workshop of a veteran machinist for more than two years before starting work on his prototype. He began, fittingly enough, with the hands. Together, the hands account for 202 of the completed figure's 920 parts. Once they were finished to Ho's exacting standards, the rest of the body had to measure up.

Working primarily with a lathe and a milling machine, using a number of custom fixtures of his own design and construction, he spent more than six years refining the design before fixing it, in 2005, as *Zoho Artform No. 1*.

Made almost entirely of bronze and stainless steel, *Artform No. 1* was produced in a limited, numbered edition of 25. Not counting its switchable magnetic display base, each figure weighs a bit more than 17 pounds, stands almost 17 inches tall, and has 85 moving parts, allowing remarkably lifelike and expressive postures. The piece was featured on the covers of *Scientific American* and *Bright* magazine, and earned Ho the distinction of being featured in Joe Martin's Internet Craftsmanship Museum.

Following the success of *No. 1*, Zoho International has started production of *Artform No. 4*, a figure built to the same pattern as the first statue, but substituting anodized aluminum, in an array of colors, for the original bronze parts.

—Sean Michael Ragan

+ zohoartforms.com

Mike Schropp

Brick Tower of Superpower

Using more than 2,000 Legos and some mad computer skills, **Mike Schropp** of Livonia, Mich., built a fully operational supercomputer that's not only awesome, but helps in the fight against diseases like cancer and HIV.

The machine uses three Intel Core i7-2600K Sandy Bridge 3.4GHz processors overclocked to a full 4.7GHz, three Asus P8P67-M motherboards, 28 gigs of RAM, and just one Antec HCP-1200 power supply. Intel's Core i7 is unlocked for modifications just like this, so the skill once required for such a task has now been eliminated, as well as much of the risk. And the case is constructed mostly of Legos!

"Legos seem to have an uncanny ability for multiplying in my house at an almost exponential rate," says the 29-year-old race engine builder and designer. "First you build models, then it's *Star Wars*, then it's your phone, your jewelry. Before things are said and done you've got nooks, bins, and chests full of them. I've been addicted to Legos for longer than I can remember, so when the opportunity comes up to work on a new project of some sort, the question that invariably arises is, 'Can I use Legos?'"

But he didn't just build the machine as a way to offload some extra Legos — it was also for a good cause. It's connected to the World Community Grid (WCC), which uses distributed computing to tackle humanitarian projects, like medical research. The WCC currently has almost two million connected devices and makes its technology available to organizations whose research might otherwise not be completed due to the highly prohibitive costs of computer infrastructure.

Mike Schropp could very well be the next Lego superhero minifigure — sorry, Batman!

—Jerry James Stone

+ totalgeekdom.com/?p=572

Szymon Klimek

Miniature Motion

Without an everyday reference for a sense of scale, **Szymon Klimek**'s intricate mechanical creations could easily be mistaken for twice their true size. Made from 0.1 millimeter sheets of brass and bronze, Klimek's miniature machines dance effortlessly in wine-glass enclosures that measure little more than 4 inches across.

Klimek's latest creation, *Sponge*, is a steam engine-like machine named for the lattic work of tiny, interconnected brass pieces that expands and contracts as the engine runs. Sitting in a wine glass about a foot tall, a small silicon solar cell powers a concealed electric motor, which drives the 3-inch flywheel.

He doesn't work to a specific scale, but customizes his designs for each glass: the opening of *Sponge*'s wine glass and the diameter of its flywheel differed by less than a millimeter. CAD programs assist with design, and Klimek, 57, assembles most of the machinery outside of the enclosures, cutting and shaping the pieces by hand. He says the wine glasses lend a bit of elegance to the display, and the spherical shape allows viewers to see the work from any angle. Sealing the top and gluing the machines down with clear resin also protects the delicate pieces from dust and curious fingers.

Living in Poznań, Poland, Klimek entered into the world of small-scale making in 2004 with a miniature steam locomotive and coal wagon, measuring about 3 inches. He's built close to a hundred handcrafted brass and bronze miniatures, including ornate carriages, early 20th-century roadsters, and yes, even a ship with billowing sails that fits in a wine glass. Since 2008 he's created nine "active devices."

Next, Klimek wants to tackle a more challenging material: steel. —*Craig Couden*

edrobiazg.com.pl

Bob Geile

Please Seat Yourself

In developing countries — where roads look like off-road, sidewalks are as rare as wheelchairs, and nothing's as rare as cash — a mobility issue can create a major drain on a family's already sparse resources. That's why **Randy Geile** designs inexpensive wheelchairs using readily available parts.

The price of a stock off-road wheelchair starts at a couple grand and skyrockets quickly. Geile's contraptions, mainly made of scrap wood and used bicycle parts, might cost $25 (and a little sweat).

Early designs had some simple metalwork, but working in Rwanda steered Geile toward wood. "Whatever they're making there, they're making of wood," he explains. "Metal is rare. Who has a welder? Even finding a drill is difficult, and someone who knows how to use it even harder. But they have woodworking tools and skills."

Each chair design is inspired by a different purpose. Whether for simple outdoor use, distance hauling, gardening, or even kayaking, the chairs all satisfy Geile's intent to improve independence and productivity. "In Rwanda, if one person in the household is disabled, someone needs to care for them constantly. If you can help them be independent, you're freeing up the caregiver as well."

The designs themselves leave a lot to the imagination. "Every bicycle is different; every body is different; every disability is different. You don't have to show them exactly how to do it, just that it can be done. The first time they see this chair go across the grass, they go, 'Aha!' So I just give them enough information to get them started down the right path. They get some skin in the game, get it exactly how they need it, and come up with their own good ideas." *—Gregory Hayes*

+ rgat.net

Maker Faire®

The Greatest Show (and Tell) on Earth!

A two-day, family-friendly festival of invention, creativity, and resourcefulness, and a celebration of the Maker Movement.

Take a tour with young maker Super Awesome Sylvia!

Hi! I'm Sylvia Todd, a 10-year-old girl from northern California. I love to make things, and teach other people! In fact, I have an online show called "Super Awesome Sylvia's Mini Maker Show," where I explain how to make everything from crazy putty to a no-heat lava lamp. You should check it out!

Once a year, MAKE puts on Maker Faires in the San Francisco Bay Area and in New York, and they're *amazing*. I've been a few times now, and I'm pretty sure there's nowhere else on Earth where you can see the incredible things you see at Maker Faire!

Check me out at sylviashow.com

Get soaked with Coke and Mentos.

Do you know what happens when you drop a Mentos into a Coke? A soda *explosion*! I got to the Coke Zero and Mentos Fountains show early to be in the front, and got totally soaked in soda, and it was awesome! You can stand farther back and stay dry, too. That's what my parents did. Afterward I got to go up and say hi and take home my very own minty soda.

Touch and experience something crazy!

Have you ever felt the urge do something daring or dangerous? Maker Faire has the stuff that's safe to try, but still crazy daring fun! I rode a bike that turned the wrong direction, climbed into a giant rocket, and pulled a 20-ton rock sculpture by a rope!

Look for Sylvia on the cover of MAKE's *School's Out* special edition, on newsstands May 29!

Me with Adam Savage!

Meet all the awesome and interesting makers in person!

Maker Faire has amazing projects and what's super awesome is that you can ask the people who made them anything you want! They all want to show off their hard work and help everyone understand how their projects are made. That's what makes Maker Faire the best place in the world. Here you can see me with the amazing Adam Savage, of television's *MythBusters*! I was stoked to meet him. He's so nice!

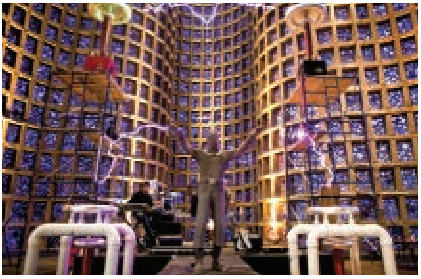
Want to visit a Maker Faire in your area?

SEPT 29–30, 2012
New York Hall of Science
makerfaire.com
NEW YORK

MAY 19–20, 2012
San Mateo Event Center
makerfaire.com
BAY AREA

Maker Faire is brought to you by the folks at MAKE magazine, and they put on two flagship faires each year: one in the San Francisco Bay Area and one in New York. There are also smaller featured faires in Detroit and Kansas City as well as mini Maker Faires popping up in cities all over the world. To find a faire near you, go to makerfaire.com/map.

Feel the buzz of Arc Attack!



The only giant Tesla coil band I know, Arc Attack is loud and bright and awesome to see! Adam Savage even got in the Faraday cage during a song. They also played the *Zelda* theme song (and *Star Wars* too)!

Build your own projects — and play with them.

3, 2, 1, blast-off! I made my own rocket and launched it. The best part was pressing the big red button! Remember: "Failure is always an option!"

Be inspired at Bazaar Bizarre.

The best handmade crafts: stuffed animals, hats, crochet, clothing swap and refashion, and more! I love it — sooo cuuute!!

SOAPBOX

By Phillip Torrone, Open Source Enthusiast

Zen and the Art of Making

LATELY I'VE BEEN THINKING ABOUT how much fun it is when you're a beginner at something as opposed to being an expert. At some point, we all become experts at one thing or another. I really want to avoid being an expert in some things, only so I can continually look forward to learning more without the burden of being an expert. Being an expert means your journey is somewhat over.

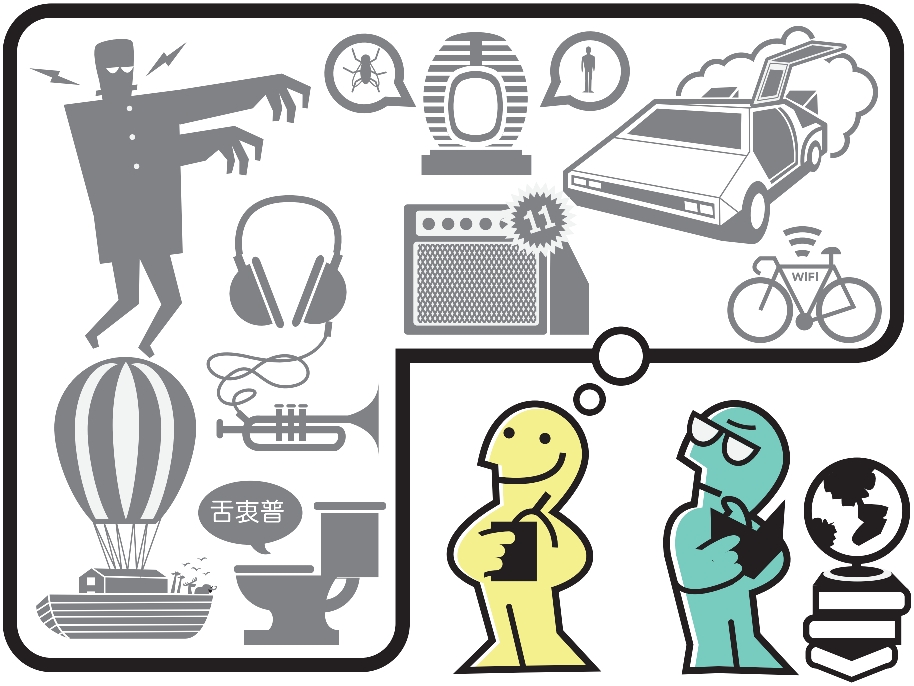
A beginner can imagine more than an expert because a beginner doesn't see constraints yet. Kids are the same way — they approach things with an open mind because they haven't been told "you can't do that" yet. Beginners aren't billing someone for their time — it's not a job, and time doesn't matter. Beginners (and kids) usually have more time than money. Beginners aren't collecting trophies (yet) — they're exploring. If you don't know the boundaries of something, for a brief time your ideas are boundless.

Experts stay still; beginners are constantly moving. An expert can point out the difficulty in every project, while the beginner can only see possibilities (and later, many ways to make mistakes). The reward for beginners is not the stuff they make, it's the person they become because of the stuff they make and share. Beginners need to practice a lot; experts need to talk more than practice. Beginners do very simple things before they understand what they are doing. Experts struggle to make things simple because they want to put everything they know into something, to demonstrate their expertise.

Beginners share their mistakes; experts hide them. Knowledge is one of the few things that doesn't diminish the more you share it. I probably read about 1,000 messages a day across mailing lists, forums, customer support emails, Google+, Twitter, and more. Beginners can celebrate failure while experts rarely admit it. For a beginner, all the obstacles, failures, and challenges are the path ahead. Beginners usually don't have any fear; they just make things — maybe it doesn't work out, maybe it does — but they don't have the same risk aversion experts tend to have.

Beginners get the satisfaction of solving many small problems that are wonderful milestones to keep motivated. Experts build bigger and for longer, so when something goes wrong it can really crash hard. The little problems a beginner solves are like weeds in a garden: you find them and use them for mulch — they're fuel. Eventually you might have a manicured estate, but I think the small garden is more fun and approachable. More people can participate because the fence is lower, or not there at all.

Once you get enough experts together, that's when the infighting usually starts. Even The Beatles fought with each other about who was the best. Experts start to see the tiniest differences between each other and (usually) fork their efforts. It might be, over the phrasing or titles of efforts, what licenses they use or don't use, who is more pure than someone else. Beginners don't know enough to care about these things yet — it's the freedom beginners enjoy, even if it's just for a short while. Beginners tend to see what they have in common with each other; experts can only see the differences. Many experts don't want to share their knowledge, and beginners don't have anything to share yet other than encouragement and enthusiasm for other beginners. Experts like to defeat each other, often publicly; beginners conquer themselves and their own challenges, and the experience cannot be taken away by anyone. Beginners don't have strong opinions — they can't effectively bother each other yet.



Juan Leguizamon

Beginners can take more risks than experts — they start with zero, so there's nothing to lose. Experts worry that if they're experts in one thing, they'll need to be experts in other things, otherwise their expertise could be questioned. For experts a lot of things are easy because they've done them so many times. Experts become impatient (with themselves and with others); beginners are patient and brave, because they don't yet know it will become easy. Experts have pride; beginners can't deceive themselves so easily.

Now is a fantastic time to start out making things. With 3D printers, laser cutters, open source hardware, TechShops, hackerspaces, and Maker Faires there's never been a better time. I'm sure every generation says that, but I really do think it's true. Starting out now, you get to explore more, faster, cheaper, and with more people. This is all new stuff too — it's hard for anyone to be an expert yet. This phenomenon happened with homebrew computers, and it happened with the web. In the maker world, we're all still figuring a lot of this out. There's still plenty of time before we're all experts.

Some of the most talented and prolific people I know have dozens of interests and hobbies. When I ask them about this, the response is usually something like, "I love to learn." I think new discoveries and the joys of learning are the crux of this beginner thing I've been thinking about. Sure, when you've mastered something it's valuable, but then part of your journey is over — you've arrived, and the trick is to find something you'll always have a sense of wonder about. It's possible to be an expert but still retain the mind of a beginner. It's hard, but the best experts can do it. In making things, in art, science, engineering, you can always be a beginner about something you're doing — the fields are too vast to know it all.

If you don't know the boundaries of something, for a brief time your ideas are boundless.

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

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.

Maker

THE HIGH-TECH HOBBITS OF TROUT GULCH

These cutting-edge animators are creating a live-in hackerspace in a California forest.

By Jon Kalish

In the mountains outside Santa Cruz, Calif., an intentional community is under construction. On 10 hilly acres in Aptos, three filmmakers who live in tiny houses and their friends have established a sort of rural hackerspace where nail guns are more prevalent than soldering irons. The compound also has a small organic farm. The guiding philosophy can be summed up in three letters: DIY. This utopian outpost is called Trout Gulch by its inhabitants.

"We're building a 21st-century Hobbit village in which things are extremely bucolic and integrated into nature, but we're also embracing the best of technology," says 29-year-old Isaiah Saxon, who grew up on the property and returned with two filmmaking buddies, Sean Hellfritsch and Daren Rabinovitch.

This back-to-the-land trio has a digital animation company called Encyclopedia Pictura, which is very much in demand and affords them the luxury of not having to worry about the rent. So they manage to balance lucrative film gigs with their zeal for DIY projects at the Gulch, as it's known.

Ever since they made a big splash with a music video for Icelandic pop diva Björk, there's been a steady stream of offers to work on videos and commercials, from the likes of Sprite, Jeep, and Honda. So far they've only agreed to work on two: one for the video game *Spore* and one for AT&T.

"We'll only do advertisements for products we use," explains Saxon, the tall, slender filmmaker. "We could certainly be maximizing our potential to make money right now, but that would hinder and slow down the development of this neighborhood that we're building. It would take us on a road to possibly an empty existence."

Jon Kalish (jonkalish@earthlink.net) is a Manhattan-based radio reporter and podcast producer. He covers the DIY scene for NPR.

Trout Gulch Farms

WOODLAND PIXEL PIONEERS (From left to right) Saxon, Hellfritsch, and Rabinovitch with props from commercials and music videos. The water buffalo to the left of Saxon was used in a Björk music video.

Scenes from the Gulch

Their existence might strike some as downright idyllic. Visitors to the compound are immediately taken by the outdoor kitchen and dining area, which is accessed by a long flight of wooden stairs from the dirt road that runs through Trout Gulch. The food prep and eating is done under a 1,000-square-foot canopy made from redwood logs and corrugated roofing. For baking, there's an igloo-shaped cob oven the Gulchers built out of earth, chunks of broken concrete, and cement. A large redwood slab serves as a kitchen counter.

Their refrigerator, also outdoors, is actually a commercial freezer that was being discarded by neighbors. Like so many of the hacks and mods done here, the Trout Gulch boys learned how to do the conversion on the web — in this case from the community of home beer brewers. They installed a thermostat controller on the freezer to make it act as a refrigerator, but it's much more efficient than a traditional fridge. Inside is often a stainless-steel pail of fresh goat milk. The three filmmakers take turns milking goats.

"If you have to face the weather while you're cooking, it kind of brings you closer to whoever you're cooking with because you have to endure the wind or the dampness or the scorching heat with the flies," says Cole Bush, one of the 12 people who currently live at Trout Gulch.

But having an outdoor kitchen has its advantages.

"You never sweep," observes Sean Hellfritsch. "You can just pour stuff right on the ground and then kick some mulch over it and you are building soil. I love that."

Hellfritsch, 28, knits his own socks and made his eyeglasses frames by carving pieces of redwood and using rare earth magnets instead of hinges. Not surprising for a guy who was taking apart stereos at age 6 and taught himself stop-motion animation with his parents' camcorder at 13.

Hellfritsch got a used motor kit, which included a small Subaru internal-combustion engine, and installed it on his mountain bike over the rear wheel. It gets 200 miles per gallon. The Gulchers say that bicyclists who scoff at a motorized mountain bike don't get the point that it's replacing a car, not a bicycle, which is less utilitarian in Aptos' hilly environs. Hellfritsch once rode his motorized mountain bike from the Gulch to San Francisco, completing the 100-mile trip in about five hours. By car, the drive takes about 90 minutes.

Web of Knowledge

It would be hard to overstate the importance of the internet in the lives of Hellfritsch, Saxon, and Rabinovitch.

"We're self-taught in every possible area," says Saxon. "We grew up in a generation in which internet search was entirely native. Search is all about self-directed education, and all of us are extremely keen at searching and finding what we need out there to get things done. To go from complete ignorance on a subject to execution of a project within a week is pretty normal here."

Says Hellfritsch: "I probably spend 50 percent of my time on the internet reading forums. Being on a forum and trying to connect with someone or search for the stored history of that forum has been really key. I've used it a lot — even in the middle of a project."

You might expect an internet-savvy crew like Hellfritsch, Saxon, and Rabinovitch to have tons of computer gear, but the Encyclopedia Pictura office at Trout Gulch, currently located in Saxon's mother's house, basically consists of three modest worktables with MacBook Pros on them. A rhomboid-shaped nook that's too small to stand in houses the Vizard, their homemade 3D viewing system. It consists of two LED computer monitors and a mirror. They

SHACKS OF THE SHIRE (Clockwise from top) Rabinovitch's remote pampas grass hut, complete with 175-watt solar panel, enough for his lights and laptop. Saxon and Meara O'Reilly's tiny cedar house, modeled in SketchUp and handmade with love. The community kitchen features an igloo-shaped cob oven the Gulchers built out of earth, chunks of broken concrete, and cement. Hellfritsch stokes the fire for dinner.

made the Vizard before 3D monitors were available commercially.

Like so many of the objects in Trout Gulch, the Vizard was the fruit of online instructions — in this case posted by video game enthusiasts. They also built a 3D camera rig, but it mostly gathers dust these days because their animation work is now done digitally.

Hobbit Houses

At the moment there are several small outbuildings at Trout Gulch, including a tool shop, guest room, an old trailer, a hoophouse for starting plants, and goat paddocks. The compound has outdoor showers and a composting toilet with two "thrones" side by side.

Encyclopedia Pictura's web intern, Rob Wilson, who can sometimes be seen carrying his pet turtle, Torta, around the grounds, sleeps in a tree house that's 24 feet off the ground. Hellfritsch and Saxon live in tiny houses not far from the kitchen. But Rabinovitch's "crib" is off the beaten track a bit.

Walk through a stand of redwood trees and up a steep hill and you'll get to his thatched hut, which is made out of *Cortaderia selloana*, an invasive species from South America commonly known as pampas grass. It took Rabinovitch a couple of months to gather enough grass for the hut, which has a pyramid-shaped glass top. There's a plastic water barrier between the grass and the canvas that lines the interior of the dwelling. The hut's door is only 4 feet tall, causing visitors to wonder whether a gnome might dwell within.

"This is basically a sleeping chamber that is built to last about 10 years, and then decay beautifully into the land and become

Jon Kalish (top, bottom left)

mulch," says Rabinovitch, 33. "We'd like to figure out how to live in the forest and not just trample everything."

As you approach the hut, a 175-watt solar panel comes into view, providing a wonderful metaphor for how the bucolic and the space-age coexist here. The photovoltaic panel, which rests on a frame made from tree branches, powers LED lights and Rabinovitch's laptop. Before installing the solar panel, he used to schlep an auto battery every day from the hut to the communal tool room, which is a bit of a hike.

DIY Heroes

One factor in the appeal of Trout Gulch is the regular visits of people Saxon refers to as "DIY Heroes." In the winter of 2010–2011 the Gulch was home to Marcin Jakubowski, a Princeton-educated physicist who settled on a farm in Missouri. His Factor e Farm is home to the Open Source Ecology project (makezine.com/go/ose), which is making prototypes for 50 different DIY industrial machines, including tractors, a drill press, a sawmill, a micro combine, a bioplastic extruder, and a compressed earth brick press that can turn out 5,000 bricks a day — enough for a home. Saxon is the project's media advisor and produced a video for Open Source Ecology's successful Kickstarter campaign.

Sean Hellfritsch knits his own socks and made his eyeglasses frames by carving pieces of redwood and using rare-earth magnets instead of hinges.

Saxon and musician Meara O'Reilly (a MAKE contributor) live together in a tiny house they built across a dirt road from the kitchen. The 160-square-foot structure has a 14-foot peaked roof and was constructed of locally harvested wood and reclaimed lumber. The cedar siding shingles were cut on one end at angles other than the traditional 90°, creating a pleasing aesthetic pattern.

True to the Trout Gulch credo of documenting and sharing, Saxon and O'Reilly have posted Google SketchUp illustrations of their tiny house on the company website, encyclopediapictura.com.

"Core to our philosophy is [the belief] that with proper documentation and proper information sharing, any averagely capable person should be able to pick up what may seem like a daunting task and learn it," Saxon says. "I think everyone in this country is capable of building their own house, even using power tools that may intimidate them."

But mostly the DIY superstars come from the San Francisco Bay Area. One of them is MAKE columnist Tim Anderson, leading the league at instructables.com. Anderson drove down to the Gulch with a lady friend on a weekend in early May to help work on the homestead and was impressed with the DIY skills on display.

"Their chops are awesome!" Anderson said of the boys at Trout Gulch. Nearby, his companion ate out of an "ice cream dish" Anderson had fashioned out of a beer can.

Many of the weekend regulars at Trout Gulch are Bay Area friends of the three filmmakers, mostly people in their 20s and 30s. They feel a part of this place.

"A lot of us who are part of the community don't actually live here right now," said May Nguyen, a graphic designer and landscaper at an urban agriculture group in Oakland called Planting Justice. "Our jobs are still up in the city but we're trying to contribute however we can."

Nguyen was helping dig a graywater wetland that uses waste water from the outdoor kitchen sink to irrigate a fruit orchard. The project was supervised by Brent Bucknum, a restoration ecologist with the Oakland-based Hyphae Design Laboratory. Bucknum met the Trout Gulch fellas up in Ukiah, Calif., where he was building a composting toilet that resembled human intestines.

"We're sort of working with these guys in trade for video production and a nice place to escape from the city," said Bucknum. "I guess we're lured by the good food, too."

Much of that food is grown in the Gulch's garden, just a few paces from the outdoor kitchen. Farmer Ryan Hett, a North Dakota native, presides over a garden with beds that are 18" deep. The garden was created by double digging: removing the soil, mixing it with compost, and then putting it back. Saxon says such beds are unrivaled for bio-intensive production. The "farm" is currently just ¼ acre but plans call for it to be expanded to two acres.

Saxon says part of the appeal of Trout Gulch is that it provides an opportunity to gain land-based experience unavailable in an urban setting.

"I think people are excited by the freedom of this place and the amazing sense of empowerment you get from being able to build everything around you," he says.

Augmenting Reality

When the filmmakers at Trout Gulch ponder the notion of building everything around them, they also think along virtual lines. In addition to animation projects, they're working on an entertainment and education medium called augmented reality (AR). Think of it as a real-time view

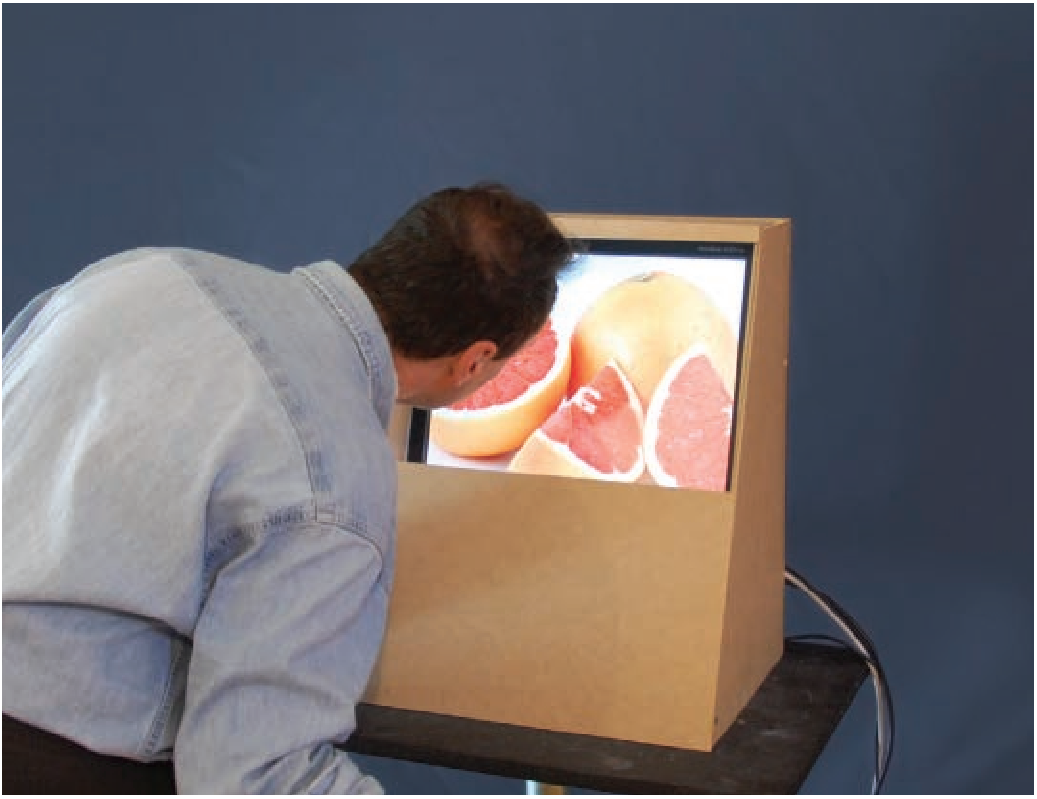
Farmer Ryan Helt works the bio-intensive raised-bed gardens of the farm behind the outdoor kitchen.

of the surrounding environment that's digitally manipulable and interactive with programmed content, not unlike walking through a video game taking place in the real world. Demonstrating augmented reality on Nintendo's handheld device, the 3DS, Saxon observed, "What you have is essentially magic."

But the Encyclopedia Pictura crew sees AR as much more than a technology for gaming.

"We see this as the big, new, creative medium for the 21st century," says Saxon. "We're trying to position ourselves as the first creative team that really understands the intrinsic power of augmented reality and creates really memorable content for it. We're going to try to be the Walt Disney of augmented reality."

They're are also working on their first feature film together. Set in Johnstown, Pa., in the year 2023, it chronicles the adventures of a 12-year-old boy and his crafty friends who leverage the talents of their town's carpenters, mechanics, and gearheads in a rebuilding effort after a devastating flood. The film's tentative title is *DIY.*



MY TV STINKS!

Incorporating smell into digital projects.

By Alex Kauffmann

As an interaction designer, I spend much of my day observing people and trying to figure out how and why they use technology. About a year ago, I participated in a group activity that involved identifying ten substances by smell alone.

Even though the smells were extremely strong and distinct (mint, shoe polish, truffle oil, lemon), none of us successfully identified more than half of them. We did, however, spend almost an hour talking excitedly about the memories certain smells evoked and how frustrating it was to recognize a smell but not be able to put a name to it.

For me, it was a revelation. I realized that in years of designing hardware and software interfaces, I'd never once considered smell, even though without any technological assistance it was powerful enough to make a roomful of adults squeal like excited children. Thus began my obsession with designing compelling smell interactions, an obsession that eventually led to the creation of Scratch 'n' Sniff, a scented digital interface.

My project brings the scratch-and-sniff sticker into the digital age. When a user scratches a display monitor, it briefly smells of whatever image the user scratched, often to the user's incredulous delight (visit vimeo.com/15881329 for a movie of people's reactions at Maker Faire New York).

How It Works

Scratch 'n' Sniff relies on fluid dynamics and some clever sleight-of-nose. Five hacked electric air fresheners loaded with custom scents

Alex Kauffmann

are hidden just below a computer touch-screen monitor.

When the user rubs his finger on the screen, across an image of a grapefruit for instance, a Processing sketch communicates the coordinates to an Arduino, which fires the appropriate air freshener.

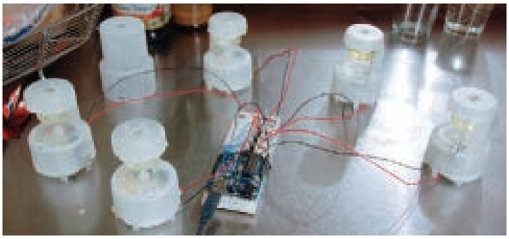
A fine mist of grapefruit-scented particles flows mostly along the surface of the screen, thanks to a property of fluid dynamics called the *no-slip condition*, which makes rigid surfaces especially "sticky" to fluids such as the grapefruit aerosol (there's a great video demonstration of this phenomenon at makezine.com/go/noslip). Diffusion into the surrounding air dissipates the smell within 5 seconds. Presto! A scratch-and-sniff TV!

There were three main design challenges:

1. Designing the interaction. I chose to mimic the workings of the scratch-and-sniff sticker not only because it's familiar to almost everyone, but also because it takes advantage of the nature of smell: the images visually reinforce people's scent perception, while scratching the screen provides a clear rationale for the strength of the smell (the longer the scratch, the stronger the smell).

2. Emitting the smell. All manner of contraptions exist for emitting and dispersing smell, from scented candles and heated oils to complex industrial vaporizers. I used Glade Wisp Flameless Candle air fresheners because they're cheap, readily available, and easily hacked to produce an almost invisible spray. (*See MAKE Volume 16, page 161 for instructions on how to hack similar fresheners.*)

3. Choosing scents. Light can be broken down into three primary colors, and all sound can be analyzed into waves of distinct frequencies, but scientists can't seem to agree on a basic unit of smell. They've identified more than 700 chemical compounds that are the basis for thousands of smells we can detect. Rather than trying to combine scents, I chose five distinct and easily identifiable smells. There are companies devoted to producing scents of everything you can possibly imagine (see Resources).



SNIFF OUT THE HACK

An Arduino Diecimila priming six scent dispensers (not for the faint of nose).

Tools of the trade: scent canister, Glade Flameless Candle, and Demeter Fragrance Hershey's chocolate scent.

Under the hood: five scent dispensers mounted just beneath and parallel to a touchscreen.

Standing in the Nostrils of Giants

I am not the first person to become obsessed with smelly media. People have been creating scent-emitting devices for years. A quick search of the U.S. Patent Office's database turns up all sorts of odoriferous inventions. There's the "olfactory special effects system," the "multimedia and scent storage medium and playback apparatus," the "combined scent and audio point of sale display unit," and Hans Laube's original 1954 patent for Smell-

O-Vision: "motion pictures with synchronized odor emission."

The idea of augmenting cinematic experiences with smells is nearly as old as cinema itself. A mischievous projectionist is said to have used an electric fan to disperse a rose scent during newsreel footage of the Rose Parade in 1906. Fifty years later, Smell-O-Vision and rival AromaRama battled to win over the noses of American moviegoers, an ultimately futile episode that inspired filmmaker John Waters to create his tongue-in-cheek Odorama scratch-and-sniff cards. These were distributed at screenings of his 1981 comedy *Polyester*, where viewers were invited to enhance selected scenes in the movie with famously unpleasant scents, including glue, grass, and feces.

The dawn of the internet age heralded the arrival of digital scent technology. A 1999 *Wired* article profiled DigiScents, the company behind the iSmell scent generator. The unfortunately named device's creators envisioned a fragrant future in which scent-emitting hardware attached to computers and other media devices would allow content creators and advertisers to add an olfactory dimension to the web. The company sank in 2001 when the internet bubble burst, but the idea persists. It resurfaced most recently in Japan as the i-Aroma, a USB device that emits astrologically appropriate aromatherapy.

Not all smell-related innovations have failed, however. Scratch-and-sniff stickers remain as popular today as they were 30 years ago, and it's hard to open a glossy fashion magazine that doesn't contain at least one perfume-drenched scent strip. If you've walked around a supermarket recently, you've probably noticed the growing number of air freshening products, from low-tech spray odor maskers such as Febreze to motion-sensing electronic devices that dispense scent whenever you enter a room.

Many hotels, casinos, and retailers have adopted "logoscents," smells intended to enhance the emotional effect of their brands. A whole industry has arisen around the idea of ambient scent marketing. In 2005, ScentAir, a leading "scent delivery solutions" provider, partnered with long-time elevator music company Muzak — soon you'll find yourself wondering not only why you're "Singin' in the Rain" but also why you smell like it!

Designing Smelltech

What distinguishes smell technologies that succeed from those that fail is thoughtful design — design that takes into account both the science of smells and how people interact with them. Before we consider what makes smelltech compelling, let's first consider how smell differs from our other senses.

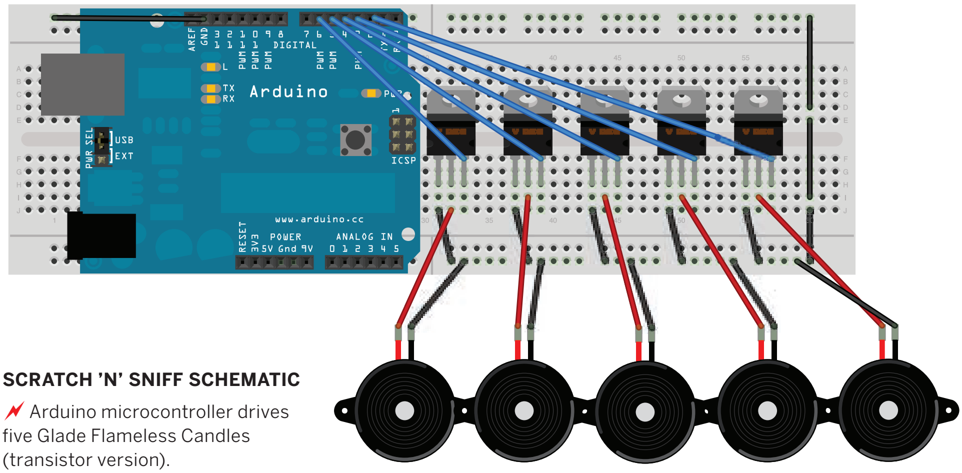
Take, for instance, the new iPhone, a prodigious piece of multisensory interactive technology. It has a high-resolution display that delights our eyes with crisp text and sharp images, sound output that floods our ears with the full dynamic range of flawlessly reproduced audio, and an interface that engages our sense of touch in increasingly novel ways. It's not edible, so Apple's engineers haven't spent too much time worrying about how it tastes. But why have they entirely ignored our noses?

Try for a second to imagine how the message "See you tomorrow at 4" smells, and it becomes clear that smell is not a particularly effective method of communication. Smell moves through the air slowly and unpredictably, and unlike sight, sound, and touch, it can't easily be turned on and off.

Because scents are invisible and diffuse, it's hard for people to agree on them in the absence of visual stimuli. While you and I might agree that the orange I'm holding in my hand smells like an orange, if instead I were holding a glass of green liquid that smelled the same, we may no longer agree that orange is the predominant scent. Smell expert Avery Gilbert is quick to point out that "wide person-to-person variability is a hallmark of odor perception."

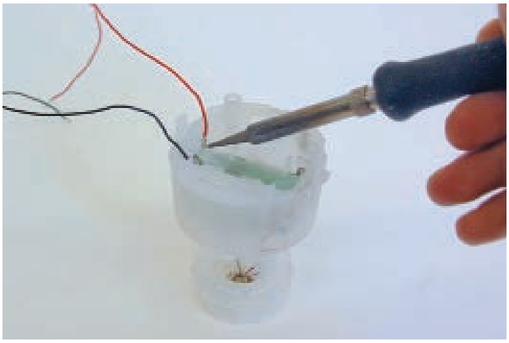
In other words, smell is more subjective than the other senses (it is responsible for the majority of our sense of taste, which is why tuna may taste horrible to one person and like heaven to the next). This also means

Augmenting cinematic experiences with smells is as old as cinema.



SCRATCH 'N' SNIFF SCHEMATIC

Arduino microcontroller drives five Glade Flameless Candles (transistor version).



that our sense of smell is more susceptible to suggestion.

A successful smell interaction will take these peculiarities into account. Here's a list of further considerations:

» Give people a clear indication of when they should smell something. Don't expect them to react to ambient smells.

» Smell takes time to diffuse and disappear. Make sure you account for this time in your design.

» Choose distinct smells. Everyone knows Play-Doh, but few will identify marjoram.

» Test your setup in a variety of conditions. Scents behave differently in large, crowded spaces than they do in small, empty rooms.

» Don't overwhelm users with smell. Olfactory fatigue sets in quickly in the presence of overpowering smells.

» Be prepared for some people to not "get" the smell. Remember, smell is subjective, so have at least a couple of different types of smell on hand.

Resources

» Demeter Fragrance Library: demeterfragrance.com

» Novelty fragrance oils: saveonscents.com

» DIY Home Perfumery: MAKE Volume 22, page 135

» A listing of hundreds of chemical compounds that make up the smells we recognize: flavornet.org

» Avery Gilbert's book *What the Nose Knows* (Crown Publishers, 2008) and his amazing smell blog: firstnerve.com

» Smell marketers index: scentmarketing.org

Alex Kauffmann is a New York-based writer/artist/designer. His work, like his life, is beautiful, simple, and absurd. You can see a bit of both at chinaalbino.com.

DIY

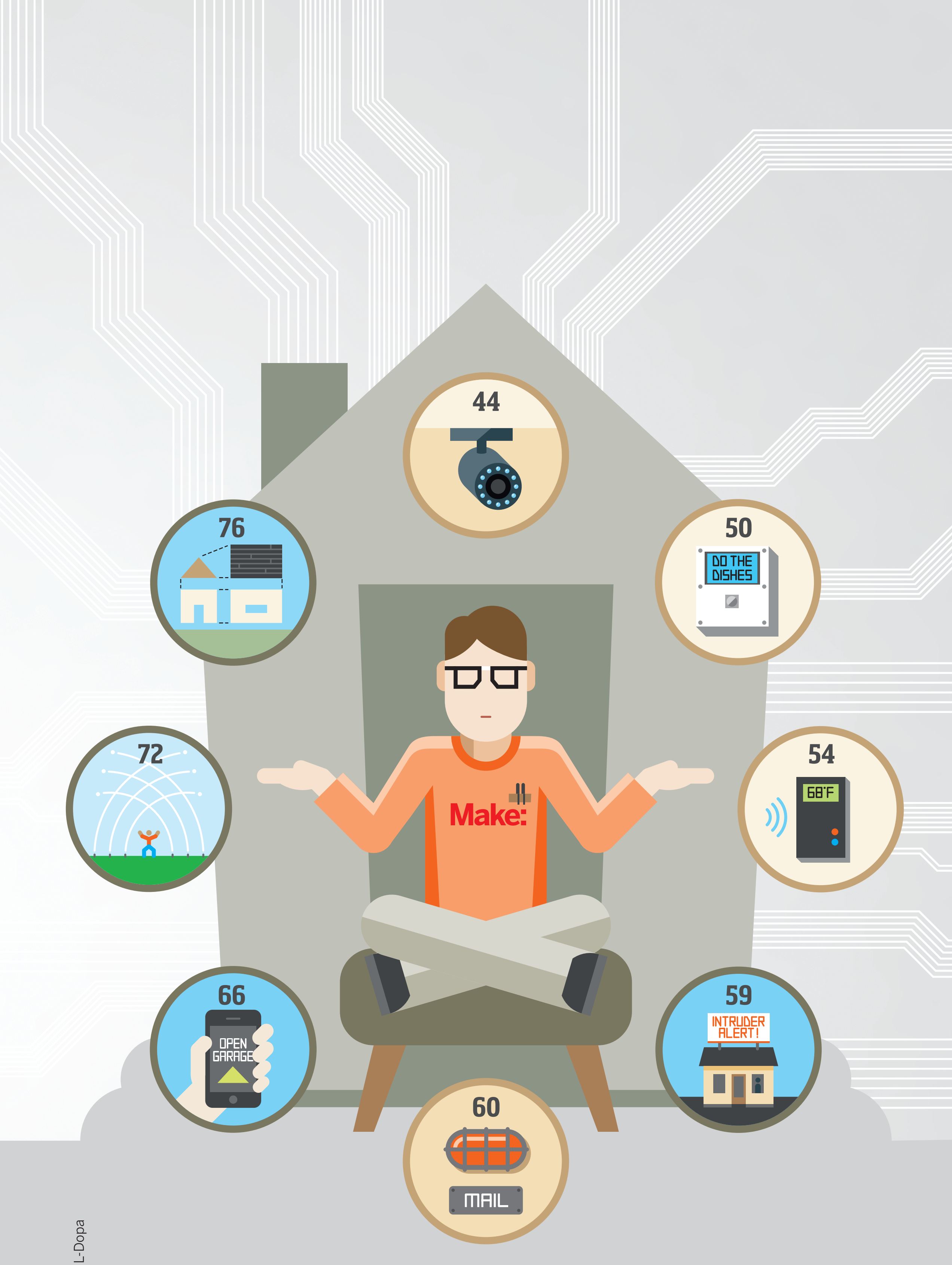
Home Automation

Tap into the elements of intelligence for smart homes.

BY BOB PARKS

To some, a smart home means greater energy efficiency — like appliances that respond to time-of-day pricing or motorized curtains that shut on hot days. To others, it's whimsy — like waterproof speakers that blast "Immigrant Song" while propane torches ignite along the roofline. Either way, it's cheaper and easier now to build the kind of smart, reliable home automation that has been promised for decades. New wireless protocols and cellphone-based interfaces make such installations extremely flexible. And by experimenting with next-gen technologies like gesture-based control and bio-engineered materials, you can turn your home into a research center that explores the technological limits of how easy, efficient, and fun your life can be.

Bob Parks is a frequent contributor to MAKE, *Runner's World*, and *Wired* magazines. He lives in Vermont with his wife and two children. Online, he can be reached at xbobparksx.com.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Control Interfaces

When the Singularity comes, you'll program your home with pure consciousness. Until then, you'll need to tell any home automation system how to behave. Even in a smart home where actions auto-trigger based on occupancy sensors or weather patterns, you need some sort of setup screen or programming interface to define your system's behavior. Some of the latest commercial graphical interfaces can provide a terrific front-end to custom hardware projects.

Cloud Service With a "cloud" interface, changes made on any web-connected device are routed back through the network to your home. Having the magic happen on a distant server means always-on status, cross-platform compatibility, and mobile access. Setting up these services — such as Digi's iDigi Device Cloud, Verizon's Home Monitoring and Control, Lowe's Iris Smart Home System, or Xfinity's Home Security — entails paying a fee, installing a home internet gateway, and logging into the company's web page.

Protocols

Communications protocols dictate how well the automated devices in your home talk; they can mean the difference between a sprinkler system that turns off at the right time and one that floods the driveway. Some protocols send signals over electrical wires, others send them over the air. They all vary according to reliability, hackability, and security. The best opportunities are with protocols whose licensing bodies offer affordable developer kits for people who want to experiment.

ZigBee This protocol is based on the IEEE 802.15.4 standard for general-purpose wireless, plus some additions owned by the ZigBee Alliance (zigbee.org). It works on both 915MHz and the more common 2.4GHz frequency, with a range of 50 meters. Dumb nodes like sensors and switches sleep a lot, so they can run for over a year on battery power, while the rest of the system does the heavy lifting of routing the 250kbps data stream. This means you need to install at least one "coordinator" ZigBee node in a network (page 66). If you want to create the next ZigBee must-have, developer kits cost $150–$300.

Z-Wave This fast-growing standard (z-wavealliance.org) sends radio signals over the air on the 908.42MHz frequency, sometimes running afoul of cordless phones, but avoiding the increasingly crowded 2.4GHz space.

Physical Interfaces

Getting signals to zip around your home is one thing. The real challenge is ensuring that they trigger the intended actions. At the edge of the network, proximity, temperature, infrared (page 118), and other sensors provide inputs to the controller. And for outputs, devices need to translate commands into steps, such as turning on a 240-volt power supply or operating a window-blind servomotor, then report back on device status to confirm success of the mission. (All protocols except X10 have a feedback system built-in.)

Plug-In Switches The simplest modules plug in to wall power and control any device that you plug into them. All protocols have such wall warts (prices vary from $10 to $200) as well as receptacles you can install in-wall for a seamless appearance. You can also control an outlet from a microcontroller using the PowerSwitch Tail II, which simply takes a digital pin output (3–12V DC, 3mA–30mA) to switch an integrated 120V AC, 15A plug.

Built-In Control Devices All home automation protocols feature

Home Computer With a PC or Mac wired into your system, it's easy to make changes to your setup. You can do so from the computer room or outside the home using remote-access software. But if you're energy-minded, remember that the machine must run continuously, with a load of at least 50 watts. That said, a computer-based interface offers the most flexibility for homebrew automation or security projects, like the Webcam Security System (page 44), especially if you're conversant with C++.

Commercial Touchscreen Hardware/Software High-end automation systems such as AMX, Control4, and Creston use custom tablets that you carry around the house. These systems, and lower-cost packages, also offer iPad apps and sometimes iPhone and PC-tablet apps, as well.

DIY Control Screen and Web Interface You can make your own controller by connecting an Arduino microcontroller to buttons and a character LCD screen (page 54). Ladyada.net has a great tutorial on how to do this. With an Ethernet shield (or other interface) on the controller, you can run a simple web server that takes commands and reports device status via a private web page, and syncs up with other Arduinos by accessing the same server location. One limitation of putting a web server on the Arduino itself is that it will generally limit its access to the same network. So if it runs on a private port, the Arduino won't also be able to pull data from the open web.

It's reliable, power efficient, and ranges between 30 and 100 meters depending on obstructions, but sends a meager 9.6kbps signal.

Insteon Compatible with the well-known X10 protocol, Insteon is the only system that sends signals on electricity lines and over-the-air radio at the same time, giving you double coverage. Many inexpensive devices for the reliable system are for sale on the Smarthome site (smarthome.com) and around the net. Want to mess around with it? A developer kit is $250.

X10 This powerline standard from the 1970s (x10.com) is the most mass-market option, although it can be sluggish and susceptible to interference: in one test, an X10 light switch inexplicably turned off whenever I played Stevie Ray Vaughan on a nearby stereo. There are no prefab developer kits, but you can read, write, and program X10 with an Arduino and a $15 plug-in device called a PSC05 (page 60). (Also note that inventor X10, Inc. is going out of business, resulting in dirt-cheap X10 gadgets coming to market as hacking fodder. For instance, a cheap light dimmer can be modified to control a motor.)

Wi-Fi Many very cool home automation gadgets, such as the Nest and Ecobee thermostats, and Belkin WeMo devices, use ubiquitous wi-fi. So you'd think the wireless network standard might be a good alternative for DIY home automation projects. But wi-fi, like networking standard HomePlug, is designed to move lots of data via TCP/IP, and it therefore demands wall current (or large batteries) and the processing muscle of a cellphone. Development boards cost $20 to $60.

Decentralized Control Some automation projects don't need a communication protocol; they run on microcontrollers, or even just simple circuitry — imparting worm-like reflexes to a smart home, rather than a central nervous system. For instance, maker Ed Rogers used a vibration sensor to automatically close his windows when a train went by, and the Notification Alert Generator (NAG) reminds you of household tasks as you walk past (page 50).

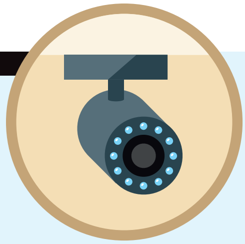
Universal Powerline Bus UPB doesn't have any developer boards, which puts a damper on things. Devices use the protocol by adding proprietary code to their firmware to send a radio signal on electrical lines using fat 40-volt pulses. The kicker? Setting up UPB requires expensive software tools, usually purchased by a contractor.

myriad gadgets and appliances with the built-in ability to receive and send signals. Screw a ZigBee or Z-Wave thermostat into the wall, for instance, and it becomes visible to the network instantly. Automation-ready devices run from mundane light switches and door locks to sprinkler systems and pet feeders.

DIY Protocol Control If you're building an interface yourself, think of it as two parts: the protocol-compatible transceiver, and the physical hardware that performs the action. Transceivers for almost all the protocols are relatively affordable; for example, $25 XBee boards that use ZigBee and other protocols, or the $15 X10 PSC05.

These connect via some interface to the physical layer, like servomotors that open blinds or turn locks, or actuators that turn on and off a water hose. The interface can be relay circuits, drivers, microcontrollers, or push button programmable prop controllers (aka programmable switches), as described in Keybanging (page 72). The Networked Smart Thermostat project (page 54) performs its physical actions by tapping into the standard four-wire control bundle used in forced-air HVAC systems.

Using this basic recipe, makers have created a vast array of custom interfaces. Anything can control anything: home theater remote controls that "change the channel" on physical reality, ovens that start cooking dinner when Google Latitude shows that you're getting close to home. In some ways, home automation is like cooking ossobuco — it's not that hard to do on your own, but it entails a lot of prep time in the kitchen.



Homemade Home Security

Build a 4-camera surveillance system and watch from any web browser.

BY DAVID BODNAR

My basement office/workshop is a fair distance from the front of the house, and I frequently want to check the front porch for mail, UPS deliveries, and the arrival of friends. I have experimented with various ways of monitoring the activity there and have found none as useful as a real-time video feed.

Getting video from a camera on the front porch to a screen in the basement is a trivial undertaking, but as projects like this are apt to do, it grew into a $200 four-camera, full-color system that can be monitored in my workshop or from any web browser. Some commercial systems can do the same thing, but they cost much more or use only black-and-white cameras. Meanwhile, I learned that switching composite video signal is actually very easy, doable with a 35¢ CD4066 analog switch chip.

START

1. INSTALL THE CAMERAS

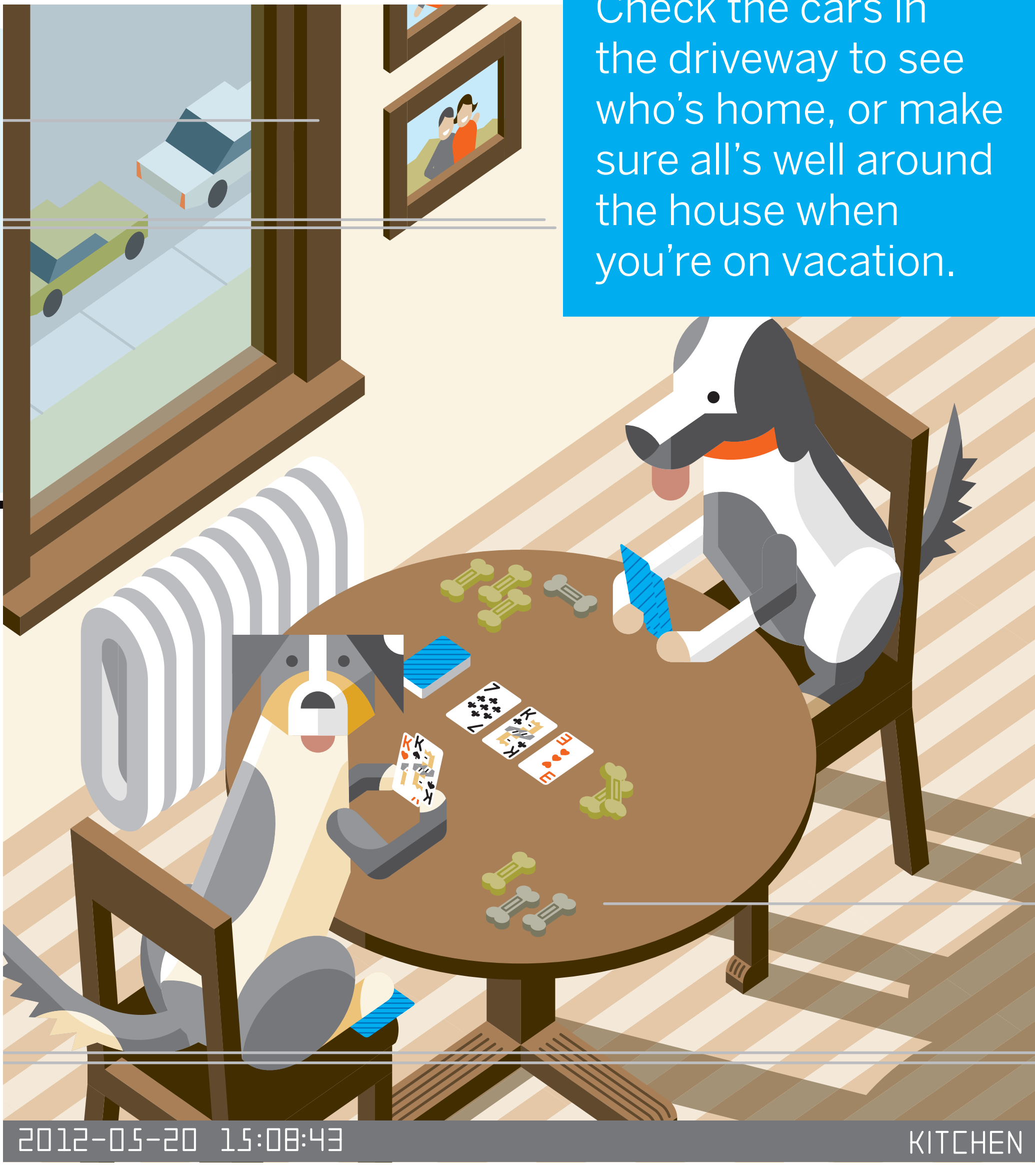
First, of course, you'll want to decide where the cameras go. I have one mounted on my front porch, aimed at the front door and mailbox; a second camera looking down on the driveway, so I can see when someone arrives by car; a third looking over the pond, garden, and garden railroad; and a fourth giving a view of the front yard. You're welcome to see the live camera feeds at n3enm.hopto.org:888 and operate the system controls at n3enm.dyndns.org:8888.

The Harbor Freight security cameras screw-mount to any beam and have a 6' cord that terminates in a 6-conductor RJ11 (technically, RJ25) telephone jack. The jack accepts an included 80' extension cable, the other end of which splits into a yellow RCA plug for composite video, a white RCA plug for audio from the camera's microphone, and a barrel connector for 9V DC from the included wall wart power adapter.

I haven't set up the software to put the cameras' audio online, but I did connect the audio from the front door camera to an old pair of computer speakers in my basement office. This lets me hear the sound of the newspaper hitting the driveway when I'm working in my office early in the morning.

The cameras and cables have proven to be weatherproof when protected from direct rainfall under a roof (Figure A), but the RJ11 connector between the camera cable and the extension cable became corroded from

Check the cars in the driveway to see who's home, or make sure all's well around the house when you're on vacation.




A


B

L-Dopa; David Bodnar (A); Gregory Hayes (B)

MATERIALS

Security cameras, weatherproof, color, with night vision and 80' cable Harbor Freight item #95914 (harborfreight.com), about $40 each, or other security camera with composite video output
Composite video to USB adapter I started with an expensive (over $100) Pinnacle device, but later tried the EasyCap, an unbranded dongle available for about $7, which has worked flawlessly for over a year.
Computer, Windows-based, with a USB 2.0 port
Web streaming software like Yawcam (yawcam.com). This free software has some features that I don't use but may be handy for others, like the ability to send an email when a camera detects activity.

For video switcher; most electronic components available at Jameco (jameco.com):
Video switcher PCB available at trainelectronics.com for $12, or download the ExpressPCB files to make your own at makeprojects.com/v/30. You can also just use a plain breadboard and hookup wire.
Microcontroller, Picaxe-14M or PIC16F684
Quad analog switch chip, CD4066
Voltage regulator, 5V, LM7805
LEDs, 3mm or 5mm, different colors (4)
Resistors, ¼W: 470Ω (4), 10kΩ (4)
Toggle switches, SPST (4) or you can use a 4-position DIP switch
Potentiometer, linear, 10kΩ–100kΩ I used a 50kΩ pot.
Capacitor tantalum, 10μF
DIP sockets, 14-pin (2)
Power supply, 9V–12V DC, 2A
RCA jacks, panel-mount (4)
RCA cable
DC power jack, panel mount to match power supply; size M and size N coaxial are common
Wire, 18–20 gauge, stranded, insulated, various colors
Project box, 6"×3"×2" RadioShack #270-1805 (radioshack.com) or similar
Machine screws, #4-40×1", with matching nuts (4) for mounting PCB
Plastic standoffs, ¾" (4) Buy them or cut lengths from plastic tubing or a pen barrel.

For Picaxe microcontroller:
Resistors, ¼W: 10kΩ (1), 22kΩ (1)
Pin header, straight, male, 3-pin for programming

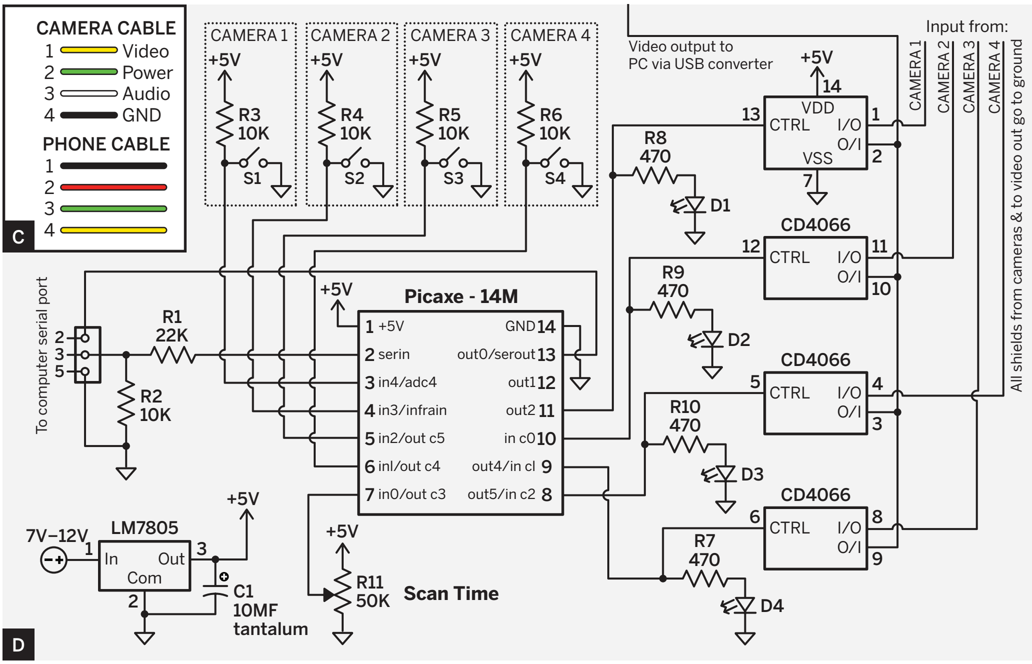
For PIC microcontroller:
Pin header, straight, male, 4-pin for programming

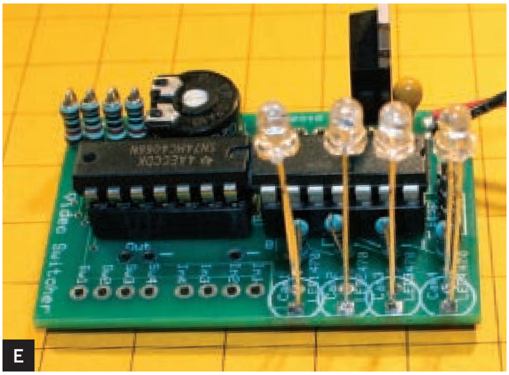
TOOLS

Soldering iron and solder
Wire cutters and strippers
Screwdriver
Drill and drill bits widths to match LEDs, RCA jacks, switches, and mounting screws

For Picaxe microcontroller:
USB programmer for Picaxe SparkFun #PGM-09260 (sparkfun.com)
3-conductor wire connected to 3×1 female pin header

For PIC microcontroller:
PICkit 3 in-circuit programmer Microchip #PG164130 (microchip.com)

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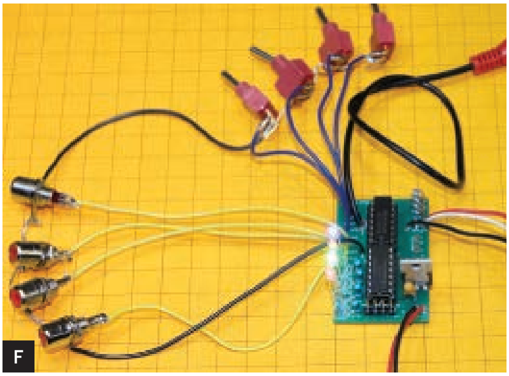
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moisture. I sealed the connector inside a plastic bag and have had no problems since.

The camera video cables will plug into a homemade video switcher (Figure B, page 45), which connects to a PC via the composite video-to-USB adapter. Using the camera cable wiring (Figure C), you can easily shorten the cables for cameras installed closer to the switcher. You can also lengthen a cable, but the video quality may suffer.

2. BUILD THE VIDEO SWITCHER

A video switcher takes inputs from multiple cameras and cycles through them at a user-settable interval (between 1 to about 30 seconds), routing each of them in turn to its single video out. It's not a complex device, and it contains just 2 chips: a 4066 quad analog switch and a Picaxe-14M or a PIC16F684 microcontroller (either one works). The 4066 routes the video inputs to the single output. Meanwhile, the microcontroller controls which cameras are active, reading from 4 toggle switches, and times the interval that each camera is given, reading the setting from a potentiometer. Four LEDs provide additional visual indication of which cameras are on.

Figure D shows the schematic for the Picaxe-14M switcher; you can see it full-sized, along with the PIC16F684 version, at makeprojects.com/v/30. The 4 camera inputs run to switcher input pins 1, 11, 8, and 4, and microcontroller output pins 2–5 (IC pins 8–11) determine which one routes to the shared video out. On the input side of the controller, input pins 0–5 (IC pins 3–7) read from the toggles and potentiometer.

To build the switcher, first solder the onboard components as marked on the PCB, with 14-pin sockets in place for the switcher and microcontroller chips. I connected the LEDs sticking up on their untrimmed leads, to poke through the enclosure with the board mounted upside down, but you can also connect them offboard with wire, as MAKE Labs did in Figure B. You can use a small onboard potentiometer as shown here (Figure E), or a longer one for making adjustments without opening the enclosure.

For the offboard connections, solder the center leads from the RCA jacks, which will carry the camera signals, to pads In1–In4 on the board. Solder one side of the toggles or DIP switches to Sw1–Sw4 on the board. For ground, run wires connecting the outer contacts of the RCA jacks and the unconnected legs of the switches (Figure F). Don't connect the DC power jack or video out cable yet.

Drill holes in the project box for the PCB mounting screws, LEDs, switches, RCA jacks, power jack, and video out cable, marking positions for proper PCB alignment. Cut the RCA cable, thread the cut end through a hole drilled in the enclosure, tie a knot for strain relief, and solder it to Video Out on the board, center contact to (+) and outer shield wire to (–). Mount everything. I mounted the PCB and controls inside the lid (Figure G, following page). If you're using DIP switches, which aren't designed for panel mounting, you can thread the wires through small holes and glue the switches to the outside. The completed

David Bodnar

unit is shown in Figure H with labels.

Rather than use 4 wall warts for camera power plus another for the circuit, I supply them all with a larger supply rated at 2A at 12V DC. To do this, cut the plugs off the included adapters and wire them in parallel to the DC power jack. Then wire another parallel pair of leads from the the DC power jack to (+) and (–) in one corner of the board. The power plugs can plug into the camera cables inside or outside the box (Figure I).

3. PROGRAM, CONNECT, AND CONFIGURE

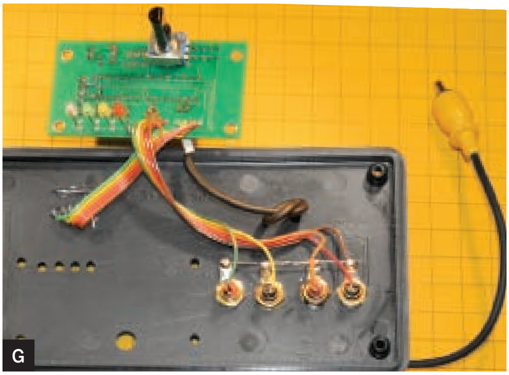
Download the project software for the Picaxe or PIC microcontroller at makeprojects.com/v/30, and follow the directions there if you haven't programmed the microcontroller before. The 2 versions of the software are almost identical. The main differences are in how variables and pins are named.

With the PIC16F684, which you program via 4-pin ICSP (in-circuit serial programming), you must configure your programmer so that pin 4 (MCLR) is set to an input pin, and you must have the switch connected to that pin (UseCamera2) set to Off. Compile and upload the code to the microcontroller, plug the chips into the PCB, and you're ready to connect.

Make sure the EasyCap unit is switched to NTSC video, not PAL. Plug it into the computer's USB port, install the driver from the included CD when prompted, and continue past any warning that the driver hasn't passed Windows Logo Testing.

Download and install Yawcam (yawcam.com), then launch it and select Settings → Detect WebCam. Syntek STK1150 should appear in the list of devices. Select Settings → Device (Syntek STK1150) → Device Properties and specify NTSC/M and Composite Video (Figure J).

From the main menu, select Settings → Edit Settings, then choose Startup and Start Stream Output. Click on Stream — the default port number should be 8081. I changed this to 8888 to accommodate other devices on my network, but you can leave it at 8081.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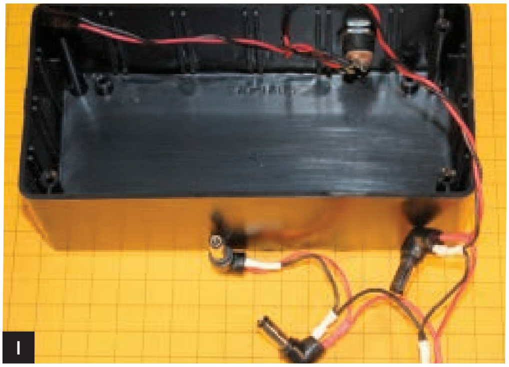
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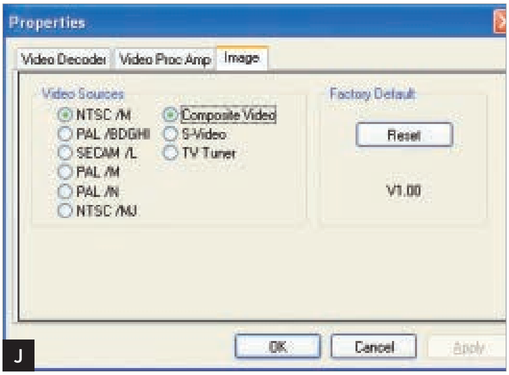
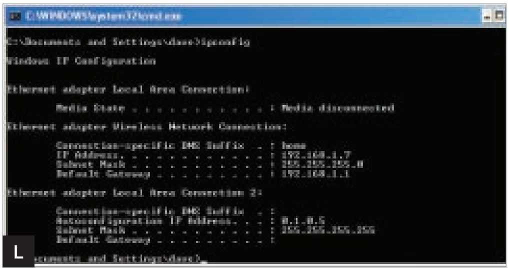
Select File → Enable Stream-output. If your computer's firewall warns you that it's blocking a port, select Unblock. To see the webcam image, enter your local IPv4 address followed by ":8081" into a web browser (Figure K). You can determine this address by entering `ipconfig` in the Windows command window (*cmd.exe*) and looking for the IP Address value (Figure L). You should see the Yawcam server screen with your live webcam image (Figure M)!





ROUTER CONFIGURATION

If you're only going to view the streaming video from Yawcam from within your home network, you're done. But to access it remotely via the web, you must configure your router or firewall to permit the Yawcam computer to be seen. This usually involves setting Port Forwarding so that the computer's IP address can be accessed from outside the firewall. See portforward.com for detailed information on how to do this with a great number of different routers, likely including yours.

If your router dynamically assigns IP addresses (most do) you will also need to assign a static IP address for the computer running Yawcam. See portforward.com/networking/static-xp.htm for instructions.

Most ISPs will change your local IP address from time to time, which stops any URL derived from it from working. To create a URL that always works, I use the No-IP Free Dynamic DNS (noip.com). To use this free service, you install a small program on your home PC that automatically checks the local IP address and redirects a web address you specify to this address. This is why the URL for my system is n3enm.hopto.org:8888. I chose the prefix "n3enm," my ham radio call, at one of the No-IP's domains, hopto.org.

CONCLUSION

I've had this system working for almost 2 years, and I rely on it throughout the day. It's really convenient to pull it up on my phone and check the cars in the driveway to see who's home, or to make sure all is well around the house when we're on vacation. Others use it, too; friends of mine who travel south for the winter check it to see how much snow is piling up back in Pittsburgh!

Meanwhile, I have experimented with X10 controllable pan-and-tilt mechanisms for the cameras, which may become permanent additions to the system. I also used EzCom2Web (easyvitools.com/ezcom2web) to add a web-based control page that lets you pan, tilt, and switch the cameras.

I hope you find this system just as useful as I have. Give it a try and let me know if I can help (dave@davebodnar.com).

+ See makeprojects.com/v/30 for code, schematics, and programming instructions.

David Bodnar is an avid electronics tinkerer, woodworker, programmer, model railroader, and cyclist whose electronic projects tend to support one or more of his other hobbies. Since he first began experimenting with BASIC Stamps over 15 years ago he has designed and built scores of Picaxe and PIC-based gizmos and gadgets, many of which are documented on his trainelectronics.com site.

The Electronic Nag

Build a Notification Alert Generator that pesters you to do your chores.

BY GEORGE TEMPESTA

Gregory Hayes

MATERIALS

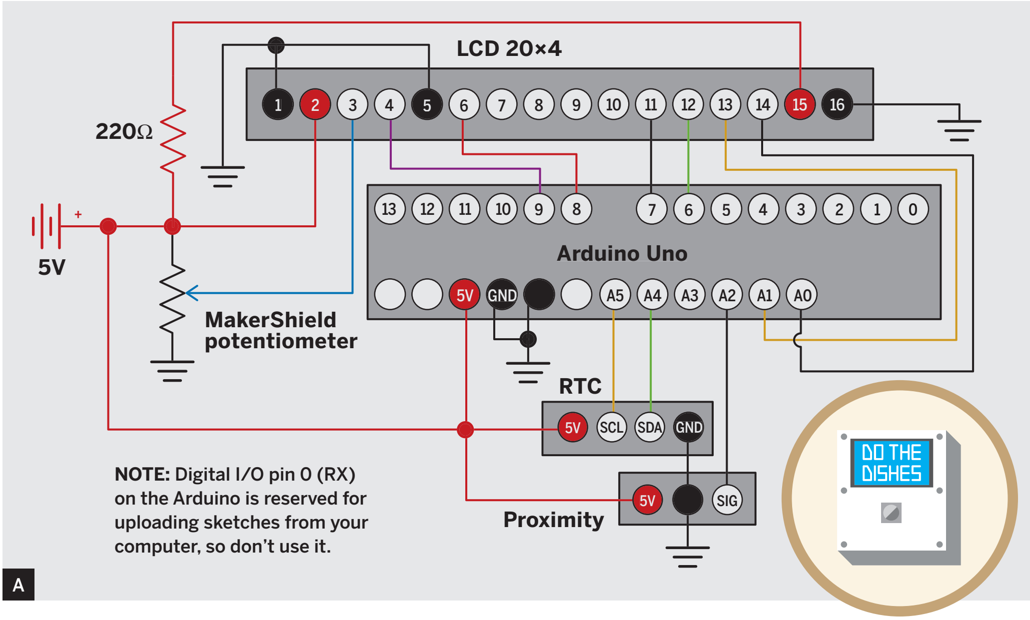
See makeprojects.com/v/30 for suppliers, part numbers, prices, and other sourcing information.

Arduino Uno microcontroller
ChronoDot real-time clock module
Wave Shield for Arduino kit
MakerShield kit Maker Shed #MSMS01 (makershed.com)
Audio speaker, 8Ω, about 2" diameter
LCD display, 20×4 characters
Proximity sensor, passive infrared (PIR)
Resistor, 220Ω
Power supply, 9V
Shield stacking headers for Arduino
Jumper wires
Cable, IDE 40-wire ribbon
Machine screws, #4-40 pan-head, ¼" (14)
Nuts, #4-40 (8)
Machine screws, #0-80 pan-head, ½", with matching nuts (2)
Standoffs, #4-40 threaded, ⅜": F-to-F (3), M-to-F (4)
Rubber feet (2)
Nail, ⅛"
Project enclosure, about 8"×6"×3"

For custom laser-cut case instead of generic enclosure:
Machine screws, #4-40 pan-head, ½", with matching nuts (20)
Acrylic, ⅛"×12"×24"

TOOLS

Computer with internet connection
USB cable, Standard-A to Standard-B
Solderless breadboard
Soldering iron and solder
Wire cutters and wire strippers
Screwdriver
Drill and drill bits (#50, ⅛", ¼", ⅜"), flush cutter, and file (for generic enclosure) or laser cutter (for custom enclosure)



It's been said that "necessity is the mother of invention." It's also been said (at least by me) that "forgetting to take out the garbage after a splendid seafood dinner is the mother of an angry spouse."

Hence the need for the NAG (Notification Alert Generator), which you can strategically mount on a wall near the bedroom to remind you of important upcoming events and tasks, such as taking out the festering garbage.

The NAG was my first real foray into building one of the crazy devices I've come up with over the years. Luckily a friend of mine who is a developer clued me into microcontrollers, and then I did some research and learned about the Arduino, its many shields, and the Wave Shield kit from the fabulous Adafruit Industries (adafruit.com), which stores WAV audio files that your Arduino can play.

When it comes to nagging, timing is everything, so this project uses a real-time clock (RTC) chip, which also contains a calendar. It also includes an LCD, proximity sensor, and a case to house the whole mess.

I'll assume the reader has the prerequisite knowledge to build and modify an Arduino project and associated sketches. If not, head over to makezine.com/arduino to get started.

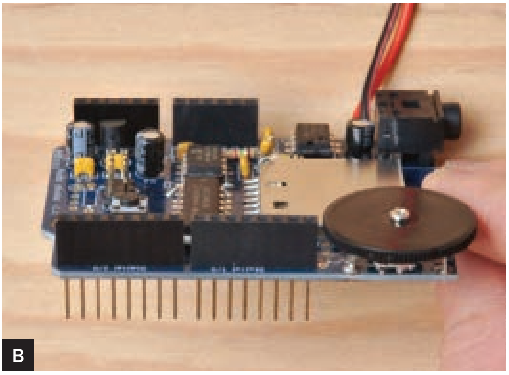
In my circuit (Figure A), many of the Arduino's limited number of I/O pins are used by the LCD and clock. The Wave Shield needs pins 2, 3, 4, and 5, but the Arduino *LiquidCrystal* code library lets you reassign LCD pins. So I made room for the Wave Shield by moving the pin assignments in the library, from `LiquidCrystal lcd(12, 11, 5, 4, 3, 2);` to `LiquidCrystal lcd(9, 8, 7, 6, 15, 14);`.

The purpose of the NAG is to nag someone as they walk by, instead of just throwing out reminders at predetermined times, unheard. To achieve this, I used a cheap infrared proximity sensor, the output of which I connected to the Arduino's analog input pin 2.

START

1. RECORD AUDIO NOTIFICATIONS

This is an opportunity to get the whole family involved in the project. We fired up my laptop with its built-in microphone and held a recording session: "It's trash night, Daddy!" and "It's recycle night, Daddy!" and so on, saving the snippets as WAV files formatted to Adafruit's specification. To cover as many bases as possible, we recorded notifications for all the hours of the day, and anything else I felt could come into play down the road.



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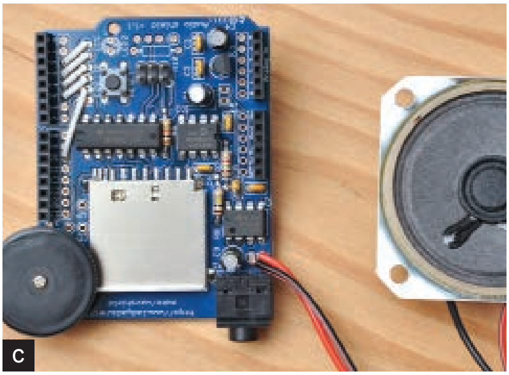

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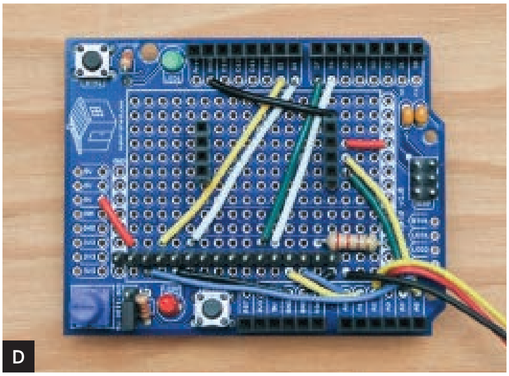

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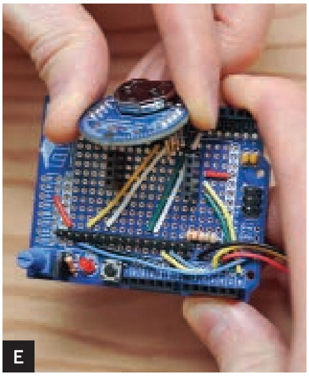

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TIP

Record as many sound files as possible in a single session, because this keeps the ambient sound and overall quality the same. Then scale back as needed.

1. ASSEMBLE THE SHIELDS AND LCD

The 2 shields come as kits, so you need to assemble them. With the MakerShield, do not solder on the short-lead 4- and 8-pin headers; these will hold the Chronodot. And with the Wave Shield, substitute shield stacking headers for the included male headers, to let the MakerShield stack on top (Figure B). Solder an 8" length of speaker wire from the speaker to the 2 audio out holes behind the jack on the Wave Shield (Figure C). Lastly, connect the LCD pins and test that it works, following Adafruit's tutorial.

2. WIRE AND TEST THE CIRCUITRY

Before committing to solder, build your circuit on a solderless breadboard. Stack the Wave Shield onto the Arduino and wire the LCD and Chronodot to their pins. Then connect the PIR sensor with the included cable assembly.

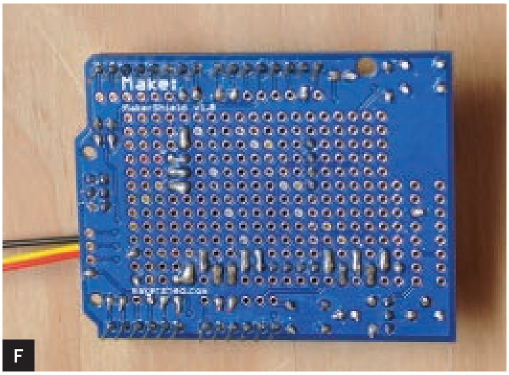
With the Arduino 0023 IDE installed (1.0 is not supported yet), download the project code *Clock_WAV_Motion_Time_Set.pde* and Adafruit *AF_Wave* library from makeprojects.com/v/30. Install the library in your Arduino directory. Read the comments in the Arduino code to change some values for testing, then upload it to your Arduino and test.

Once it checks out on a breadboard, cut off a 16-pin strip of male headers (from the Wave Shield) and cut the short-lead 8-pin header (from the MakerShield) into a 4-pin header. Transfer the wiring onto the shield, including the 16-pin header for the ribbon cable and the two 4-pin headers for the Chronodot (Figure D). Plug in the Chronodot (Figure E) and solder everything down, solder-bridging the header pins to their adjacent wires (Figure F).

Stack the MakerShield onto the Wave Shield. Attach the LCD via ribbon cable, making sure it connects to the same pins at both ends (Figures G and H). Connect the PIR sensor to the MakerShield via its included cable.

3. ENCASE THE PROJECT

At makeprojects.com/v/30 you can download a template for turning a RadioShack project enclosure into a case for the NAG, and also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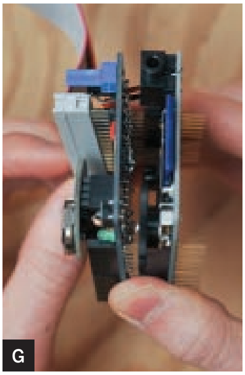
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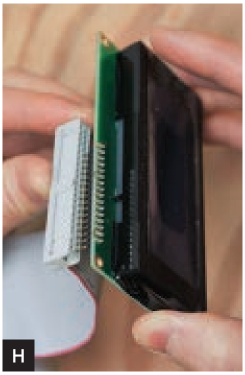
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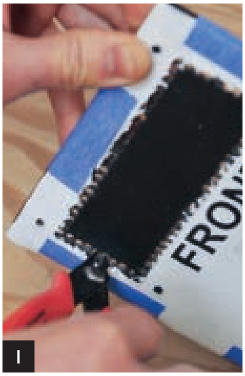
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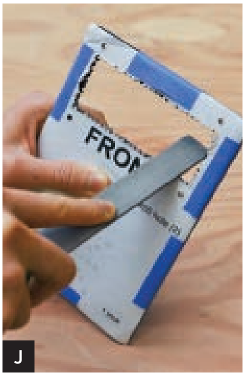

J

We fired up my laptop with its built-in microphone and held a recording session: "It's trash night, Daddy!"

DWG files for laser-cutting a custom NAG case out of acrylic. With the RadioShack box, center-punch and drill the holes, then use a flush cutter and a file to smooth the edges (Figures I and J). Mount the LCD using male-to-female standoffs and 4-40 screws and nuts; the PIR sensor with 0-80 screws and nuts; the speaker with 4-40 screws and nuts; and the Arduino using 4-40 screws, standoffs, and nuts.

With either the RadioShack enclosure or the laser-cut acrylic box, add rubber feet to the bottom corners where they will rest against the wall. You can hang the NAG on a nail.

4. CUSTOMIZE THE SKETCH

My Arduino sketch assigns the proximity sensor pin as an input and tells the Arduino what to do when it sees someone walk by. It also triggers actions based on the time or date.

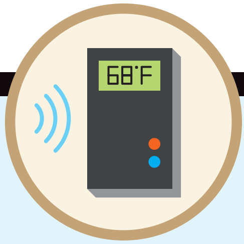
Of course, you can customize the sketch however you want. Tuesday is trash night, so mine nags whenever somebody walks by between 7 and 11 p.m. But it would be quite annoying if it did this every time, so it waits 20 minutes between nags, except for scheduled nags at 5 minutes after 7, 8, 9, and 10 p.m.

Wednesday follows the same nagging protocol as Tuesday, but with a different WAV file: "It's recycle night, Daddy!" In addition to playing proximity-triggered messages, the sketch announces the hours between 7 and 10 p.m. and 8 and 10 a.m., and on the LCD it displays messages such as "Thirsty Thursday" and "T.G.I.F." Upload your custom sketch to the Arduino, using Arduino IDE 0023, and congratulations, you're now being NAGed.

GOING FURTHER

I hope to enhance the NAG with a touchscreen so it's easy to add new events such as meetings, birthdays, and sports events. ("Don't forget to take an apple for the teacher today.") Once the touchscreen programming is working, I'll add more functionality. Just wait till the next version!

George Tempesta (oldpartsnrust@hotmail.com) is a forgetful, loving husband and the proud father of three beautiful little girls. He has always had to learn how everything works.



Networked Smart Thermostat

Control your home's heating and cooling from anywhere.

BY ERIC MERRILL

At my hackerspace, i3 Detroit, we have programmable thermostats that frustratingly reset your settings at fixed times. At home, our old thermostats just have a setting lever, and our power company has started time-of-day metering. So I decided to replace the thermostats at both i3 and home with smarter, programmable, networked versions.

Standard forced-air HVAC systems are surprisingly easy to control. The standard thermostat cable in the walls contains color-coded wires with the following functions:

R — Red — 24V AC power
Y — Yellow — Cooling
W — White — Heating
G — Green — Fan
C — Black — Common/ground, optional

The 24V AC power comes from a 5:1 transformer at the furnace. To turn on the cooling, heating, or fan, you simply connect power (R) to the corresponding wire, Y, W, or G. If you program an internet-connected microcontroller to drive relays that switch these connections, then you have full local and networked control over these functions, and it can respond to data captured online.

You may find Rh and Rc wires (hopefully labeled with stickers) instead of an R wire. These are heating- and cooling-specific power sources that should connect to the W and Y wires separately. The fan wire lets you switch the fan manually at any time, and a standard HVAC system also automatically turns the fan on when needed for heating and cooling.

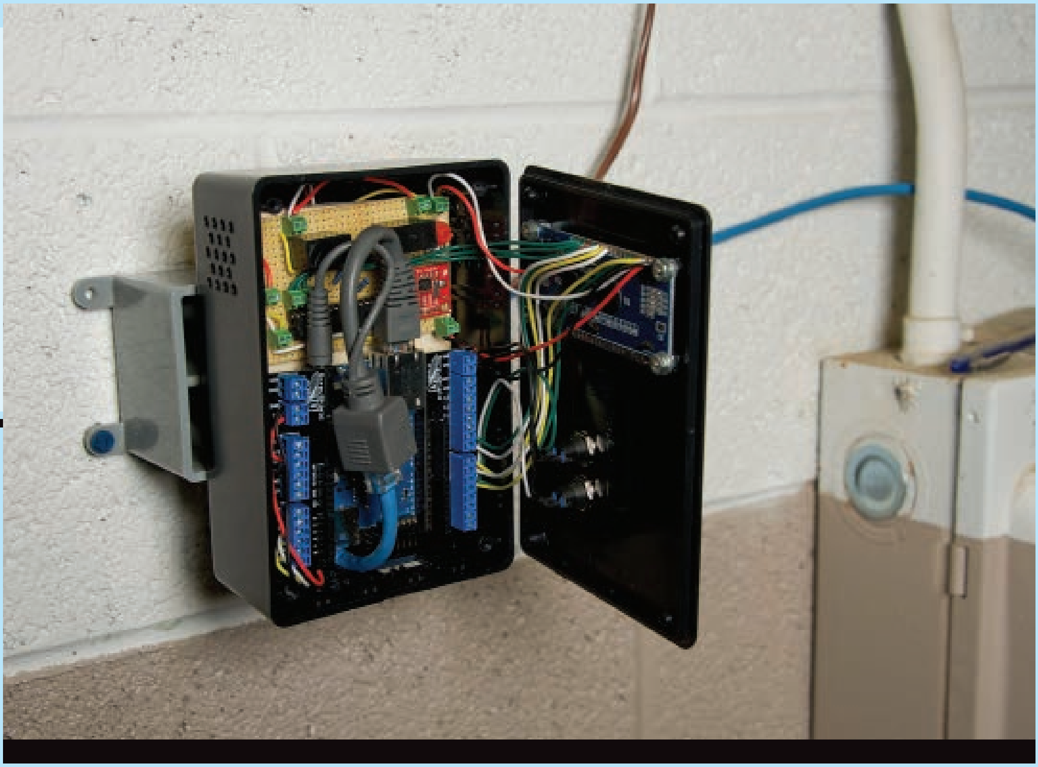
START

DESIGN OVERVIEW

The Arduino has a limited number of pins, so I used the **I2C protocol** to control the 24V relays that switch the system's heating and cooling. I could've driven these 2 circuits from dedicated Arduino pins, but the I2C protocol lets you control multiple devices with just 2 wires, which means I can add more devices to my system, like for fan control or a heat pump/dual stage HVAC, without needing more Arduino output pins. Conveniently, an Arduino I2C library lets you run I2C's 2 wires, Serial Data Line (SDA) and Serial Clock Line (SCL), off analog pins 4 and 5, and make easy program calls to each device.

I2C runs multiple devices off its 2 shared wires by giving each a unique address. Components designed specifically for I2C have jumpers or switches that configure this address, and you can give I2C addresses to simple, switchable devices (like my heating and cooling relays) by using an **I/O expander chip** like the MCP23017-E/SP. The protocol's SDA and SCL lines connect to one side of this chip, and each device connects to one of 8 control lines (GPA0–GPA7) on the other side.

To enable time-based thermostat controls, I included an I2C **real-time clock (RTC)** module, which carries a DS1307 RTC chip and a lithium battery that can supposedly power it for 9+ years. To simplify the hardware, you could omit the RTC module and use the Ethernet interface to fetch the time, although



Eric Merrill

MATERIALS

See makeprojects.com/v/30 for recommended suppliers and other sourcing information.

Arduino Ethernet microcontroller Maker Shed item #MKSP9, makershed.com. Or pair an Arduino Uno (#MKSP11) with an Arduino Ethernet Shield (#MKSP7).
Temperature/humidity sensor, Sensirion SHT11
Real-time clock (RTC) module for DS1307 real-time clock chip
I/O expander chip, 16-bit with serial interface, MCP23017-E/SP
LCD display screen, 16×2, RGB backlight
Potentiometer, 10kΩ usually comes with LCD screen, for contrast adjustment
ScrewShield Arduino prototyping shield Maker Shed MKAD24
Pushbutton switches, momentary (2)
Power over Ethernet (PoE) cable set
Transformer, 9V DC aka wall wart
CAT5 cable long enough to reach from thermostat to Ethernet and 9V DC power sources
Protoboard or perf board, about 2"×3"
Resistor, 10kΩ
Wire, 20–22 gauge, insulated, stranded various colors
DIP socket, 28-pin
Screw terminals, 2-pin (7)
Project box, at least 6"×4"×2" or deeper if you use the Ethernet Shield
Plywood or medium-density fiberboard (MDF), 6"×4"×¼" thick
Machine screws, #4-40, ¾" (12) with matching washers and nuts

For each HVAC control wire controlled (heating, cooling, fan):
Relay, 5V DC switching voltage, SPDT
Diode, 1N4002
Transistor, 2N3904
Resistor, 1.2kΩ

TOOLS

Soldering iron and solder
Razor saw or other saw for cutting protoboard
Vise
Drill and drill bits
High-speed rotary tool with cutting wheel e.g., Dremel
Hobby knife or small file
Screwdriver, slotted, small
FTDI programmer for programming the Arduino
Computer with internet connection
PHP/MySQL server (optional) for remote web control. The project will work without it.
Project code: Arduino sketch *Make_Thermostat* and web page *make_remote.php* Download at makeprojects.com/v/30.

this would give coarser time resolution.

To carry the I/O expander, relay circuits, and RTC, I built an Expander Board (Figures A and B), and used screw terminals for all the external connections.

Of course, a thermostat needs a **temperature sensor**. I used a Sensirion SHT11 2-wire combination thermometer and humidistat connected to Arduino digital I/O pins 2 and 3. You can mount this on the Expander Board, but I left it dangling on wire leads for better mounting in the project box (Figure C).

Instead of using separate cables to connect power and Ethernet from my DC transformer and router to the thermostat, I used a **Power over Ethernet (PoE) cable set** that "injects" both into one CAT5 Ethernet cable, then splits them back apart at the other end.

LOCAL CONTROL

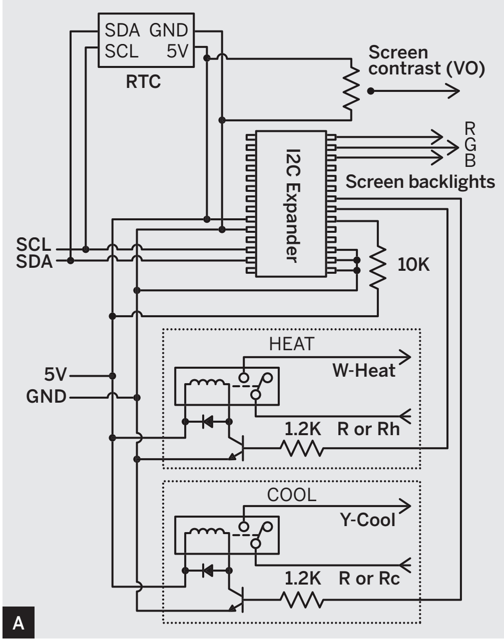
The thermostat is controllable over the network, but 2 buttons and a small LCD also support local control, like a traditional thermostat. The buttons set the target temperature up and down, and the screen displays the current setting. Figure D shows how these components connect, along with the Arduino and Expander Board. You can omit the buttons and screen to make the project simpler, and for any programming, such as time-based control, you'll use the network interface.

For the screen, I used a 16×2-character LCD and followed Adafruit's great tutorial on how to control these with an Arduino (ladyada.net/learn/lcd/charlcd.html). My only deviation was moving the Arduino digital pin connections from pins 7–12 to pins 4–9, because the Ethernet Shield needs pins 10–13. To prepare the LCD board, solder long wires onto its back for each connection needed (Figure E), and mount the separate screen contrast trimpot on the Expander Board.

CONSTRUCTION AND INSTALLATION

Cut a plywood mounting plate to fit your box, then drill and screw-mount it inside, and mount the Arduino using #4-40 hardware and spacers (Figure F). This project fits tightly

NOTE If you have a dual-stage furnace or a heat-pump system, or if you find additional or different wire colors, you'll need to do more research into your installation. The basic control scheme will be the same as described here, but the logic may be more complicated and include restrictions.



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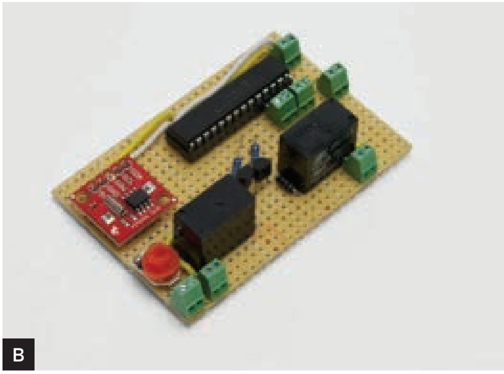

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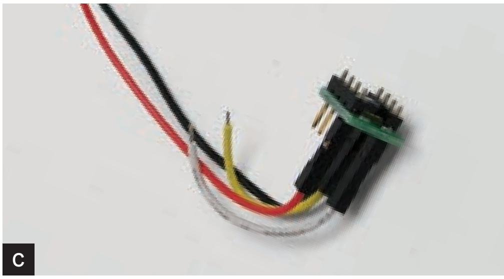

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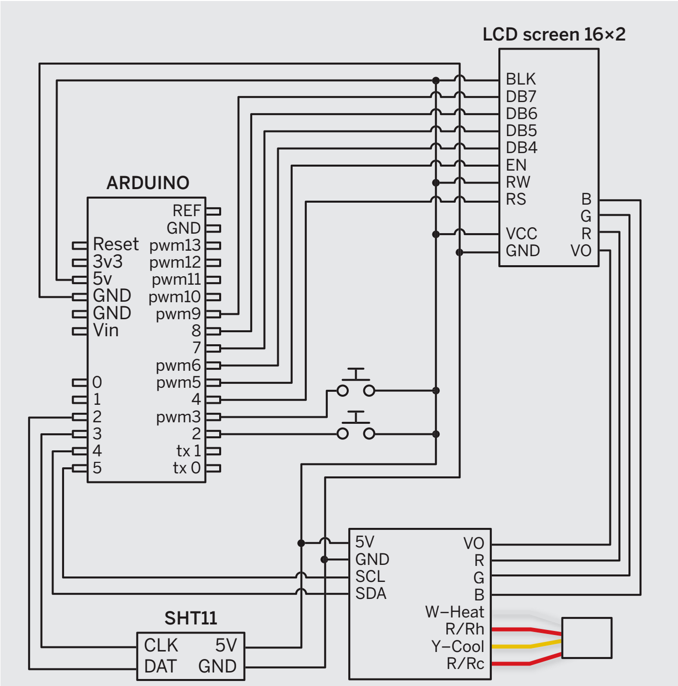

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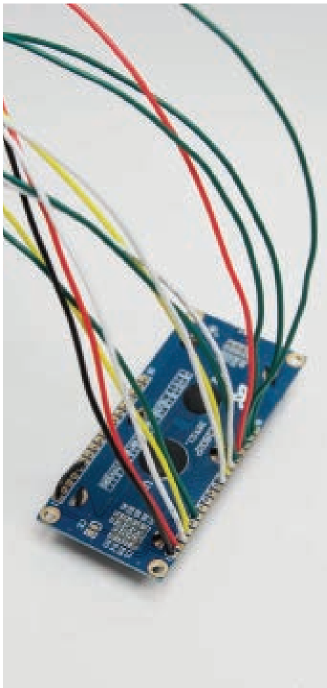

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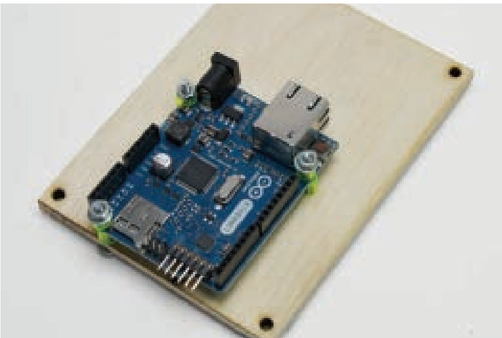

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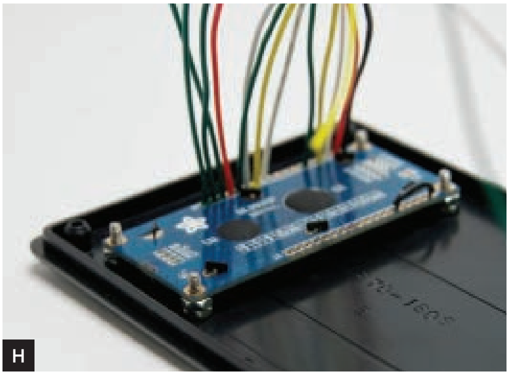
G

in the 6"×4"×2" box, so plan carefully where each item will go, to ensure that they won't interfere with each other.

Using a drill and Dremel, cut holes for the LCD screen and up/down buttons in the box's faceplate; ports for the HVAC control wires, PoE cable, and FTDI programmer in the sides; ventilation holes in the bottom and sides; and mounting holes in the back (Figure G). Mount the buttons and screen, adding spacers if needed to make the screen flush with the faceplate (Figure H, following page). Using Figure D as a guide, wire up all components.

To enable secure wire connections without soldering, I plugged a ScrewShield into the Arduino. I mounted the Expander Board over the Arduino, and wired the mounting plate and faceplate components together like a book (Figure I). The power regulator and other components in the box produce heat, so I tucked the temperature sensor into the bottom of the box, against the bottom ventilation holes. You can also drill a hole for the wires and put the sensor outside the box.

Mount the box to the wall; you can use small drywall anchors or attach it to an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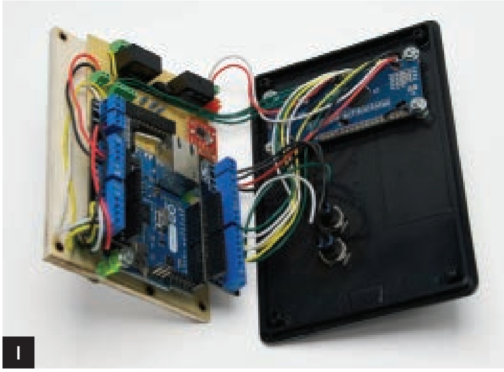
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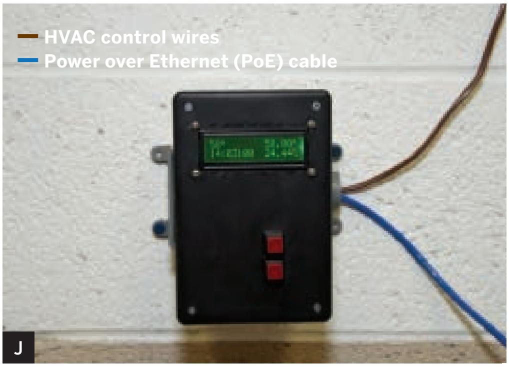


J

electrical junction box. Connect the HVAC wires to the Expander Board as shown in Figure D. You can cut off any unused wires or tape them back, making sure they can't contact anything in the box.

Connect the PoE cable pair's "splitter" to the Arduino's power and Ethernet jacks, route it out its hole, and connect it via CAT5 cable to the "injector" cable connected to power and Ethernet (as shown on page 55). Making sure all the parts are in place and have clearance, close the lid, and screw it on (Figure J).

NETWORK SETUP AND SOFTWARE CONTROL

Download the *Make_Thermostat* sketch at makeprojects.com/v/30 and follow the instructions to upload it to your Arduino. The code supports the thermostat's buttons and screen and also creates a web interface that displays the current and target temperatures and also lets you change the target.

This is accomplished in 2 parallel ways. For control within your home network, the code runs a simple web server at its IP address, which you can see by holding down both buttons. For control via the open web, the code reads and writes values to a server location, for access by a *make_remote.php* page (get this code too at makeprojects.com/v/30) on your home or remote server. This method enables multiple Arduinos to sync up, and also lets you save and change states while the Arduino is off. (The code's local-only web server is for people who don't have a server that runs PHP and MySQL; it's also faster and more reliable if there's outside network trouble.)

The *Make_Thermostat* code uses closed-loop feedback to maintain the temperature within a plus-or-minus "deadband" around the target. A larger deadband will cause the furnace to run less frequently but longer, creating more noticeable swings. A more complicated scheme is proportional-integral-derivative (PID) control, which uses learned or hard-coded information about the HVAC system to avoid overshooting the target.

You can of course modify the code to do anything you want, including learn your habits, learn PID values, and incorporate inputs from the clock or additional sensors. But to avoid damage to your HVAC system, you should avoid "short cycling" (running frequently in short bursts), and to protect your air conditioner compressor, cooling should be off for at least 5 minutes between runs.

Eric Merrill is a programmer by day, photographer by twilight, maker by night, and CEO of metro Detroit's first and largest hackerspace, i3Detroit (i3detroit.com).

NOTIFY ME NOW!

One young maker's home security system. **BY GOLI MOHAMMADI**

Cecilia Absher

At Maker Faire New York 2011, 13-year-old Andrew Katz displayed an automated dollhouse that showcased his Arduino-based Notify Me Now security system. He drummed up quite a bit of interest and inspired us all.

What motivated you to create an automated dollhouse?

I decided to install the system in a dollhouse because it would be easier to tinker with, but my main plan is to install the system in a real house. The day I came up with the idea, the dog had gotten into the garage without us knowing, and my brother snuck into my room and scared the living daylights out of me. I thought, "Well, I like Arduino, I am experimenting with ultrasonic sensors, I like my laptop, and I hate it when people sneak around. Sounds like a good project!" So I decided to create an Arduino-based secret notification system to alert me by changing a picture on my laptop's screen if someone tripped a sensor. That way, only I knew where someone was in the house.

Is Notify Me Now a prototype?

Yes, but the final system will be an improved design, with support for other sensors that an Arduino can support. I think that the basic concept is there, but it can do much more. I want to make it a device that has plugs for sensors, plugs for outputs, and a program that is completely customizable to the user. I want it to be open and free, with the ability to be used for anything.

How does it work?

The project has ultrasonic capabilities and pushbutton abilities built in natively. It also supports many other sensor types, from sound to light to pressure pads to websites. On the Arduino's startup, it takes a baseline reading of the sensors, then it checks the current sensor reading against the baseline. If there is a difference, it sets off an alarm and sends a message to the computer, telling it to change a picture on the screen. The alarm is optional, and the pictures are user-customizable.

What was your R&D process?

I had a book that talked a little bit about Processing and about the ultrasonic Ping sensors, so I started there. I also went through the online documentation about the sensors. Then I wrote a simple sketch, which would signal when a sensor was tripped, and began testing. From that point until when the Processing code was written, it was trial and error. By the end, I had created a range of values that would be accepted to trip the alarm instead of just one. This allowed for fewer false alarms. I then wrote the Processing code to get the signal, to forward it to an Arduino with a buzzer attached, and to change a picture on the screen. I did some troubleshooting, and lastly, did final tests to make sure everything worked like I wanted it to.

How did you get interested in programming?

When I went to the Maker Faire New York for the first time in 2010, I got introduced to the Arduino. I liked it a lot, but I knew I would have to learn to program it to use it properly, so I decided to take an introductory programming course on my new iPhone. Mom thought that I should take Stanford's Programming Methodology course. I really enjoyed it, and I learned a lot about Java and good programming practices. After, I also read a book on Arduino, and since then I have fallen in love with programming.

What advice do you have for other young makers?

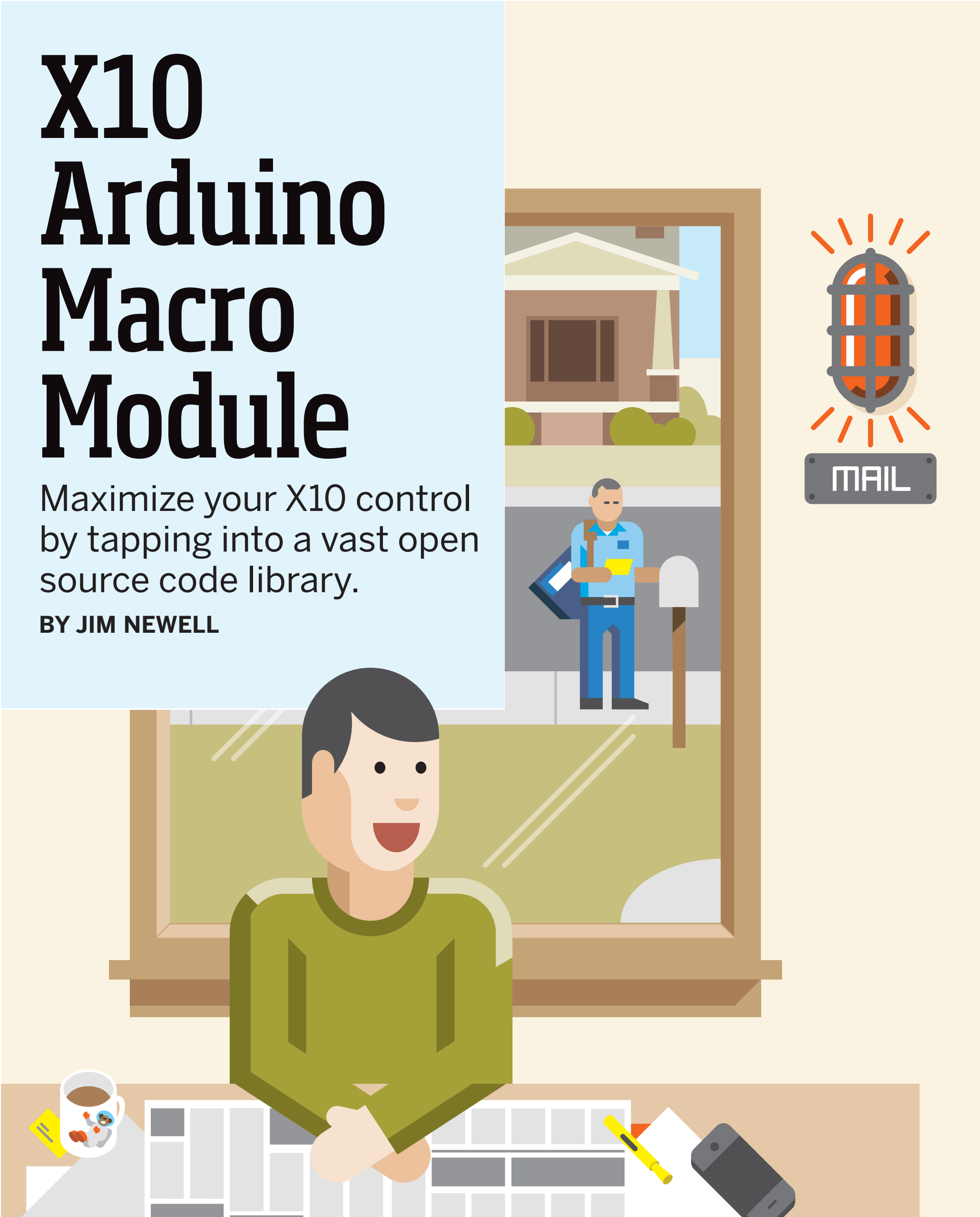
Always go for your ideas, repurpose things, and never give up. Always try an idea that you come up with, no matter how stupid it seems. It can be frustrating at times, but you need to always keep going. You can take a break, though. There is a lot of useful information out there, online and in books, so whenever you get stuck, just look for the answer or keep experimenting until you figure it out. Be persistent, only ending a project when it's done.

Download code files for Notify Me Now at makezine.com/go/notify.

X10 Arduino Macro Module

Maximize your X10 control by tapping into a vast open source code library.

BY JIM NEWELL



L-Dopa

With a little creativity, you can do some amazing things around the house.

» Place a motion detector in your mailbox, and have it turn on a light and sound a chime whenever the box is opened.

» Add a contact sensor and an X10 Powerflash module to your garage door, to sound a chime if the door is left open for 5 minutes or more.

» Put a proximity tag in your teenager's car, so that when they drive up, the porch light comes on and interior lights illuminate a path to their room — or to the refrigerator.

As a home automation buff, I've used X10 Powerline control products for over 30 years. And although the technology has some shortcomings, I still believe X10 is the cheapest and fastest way to automate a home.

One of the most powerful additions to any X10 system is macro capability, in which a controller monitors the power line for trigger signals and responds by executing timed sequences of additional X10 commands. Unfortunately, commercial solutions for running X10 macros are lacking. One choice is Windows software that must run on a dedicated, always-on PC, and is incapable of defining macros with nesting or conditional logic. Another choice is standalone X10 controller modules such as the CM11a and CM15a, but I've found these unreliable and prone to frequent lock-ups.

I have long wanted a small, reliable X10 macro module that I could program in C++, to maximize my options for coding and algorithm development. By standing on the shoulders of giants, I have created one — and the controller looks so good housed in a small jewelry box (Figure A) that my wife allows it to reside on our bedroom dresser.

My X10 macro module has 2 main components: an Arduino microcontroller and a PSC05 (or equivalent TW523) X10 Powerline Interface Module (Figure B). The Arduino runs macros that you write in C++, calling in to a great open source code library of X10 transmit and receive commands. The PSC05 is a module designed to plug into a wall socket and translate in both directions, like a router, between X10 signals carried over a 120V AC power line and wires carrying standard 5V DC encoding, as used in digital electronics.

On the low-voltage side, the module has a 4-conductor RJ11 jack for connecting it via telephone cable to X-10 control devices like home automation control consoles or wireless remote control receivers. But for this project, we'll connect these 4 wires to the Arduino.

X10 PROTOCOL

To understand how this project works, you need to know the basics of X10. The X10 protocol was first developed in the late 1970s to support home automation commands carried over house wiring, so that appliances could be turned on and off and lamps dimmed or brightened remotely, with no need for dedicated control wires. X10 commands are injected onto the power line in a binary format, where a binary 1 is represented by a 1ms burst of a 120kHz signal, and a binary 0 is the lack thereof.

Because home power wiring is noisy, these signals bursts are injected only at the moments when the 60Hz (in the U.S.) AC

A

B

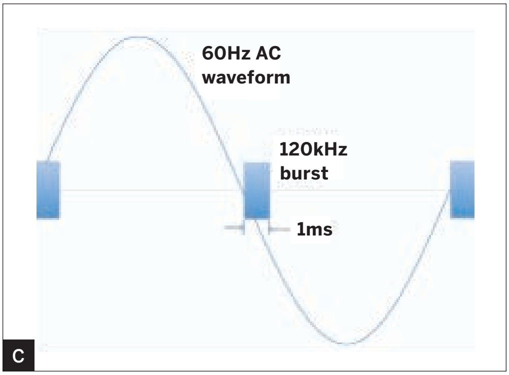
Jim Newell

power wave crosses 0, to maximize signal integrity. This happens 120 times per second (Figure C), and to accommodate artifacts from the 3-phase long-distance power grid transmission before it's split into single-phase house current, each bit is transmitted redundantly 3 times, once for each phase.

To allow remote operation, each light and appliance unit in an X10 network has its own unique 8-bit address, and X10 command sequences consist of one or more unit addresses followed by a 4-bit code for the command that is requested. The command codes include on, off, dimmer, and brighter; query and response codes for checking device status; and special commands for switching on all lights or turning off all units that share the same house code.

Device addresses break down into a 4-bit house code, usually designated by a letter A–P, and a 4-bit unit code designated by a number 1–16. You assign a unique address to a plug module by turning 2 dials on the front (Figure D), and then plug in a light or other device.

The module will listen on the power line for its address and respond to any commands sent to it. On the control side, Figure E shows a typical X10 wireless remote system. You plug the wireless receiver into the power line and turn the dial at the bottom of the remote to your house code. Then the remote's 2 columns of buttons turn on and off your 16 devices, 1–8 with the slider switch to the left and 9–16 with the slider to the right.



C

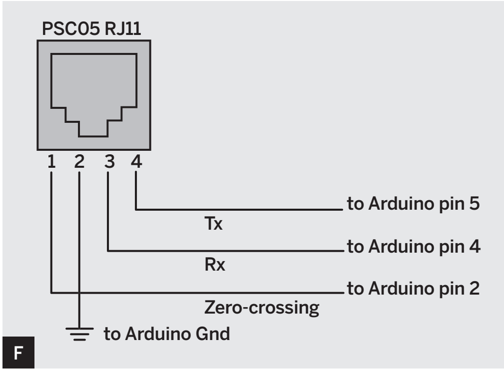
D


E

PSC05 TRANSCEIVER WIRING

A PSC05 transceiver plugged into a wall socket detects every zero-crossing on our power line, and can read or transmit any X10 data associated with the crossing. Incremental work by Tom Igoe, BroHogan, and Creatrope has produced a free, open source Arduino library for interfacing with this device, letting us communicate via power line X10 as we wish. Using this library, we don't need to know any X10 binary to program our macro module; we just need device addresses and desired functions.

The 4 connections to the PSC05 transceiver's RJ11 phone jack are, in pin 1–4 order: zero-crossing detect, which reads high (5V) for 1 millisecond after each zero-crossing of the AC wave; ground reference (GND, 0V); data receive (RX) from the power line; and data transmit (TX) to the power line. The Arduino X10 library expects these to be connected to the Arduino's digital I/O pin 2, ground, digital pin 4, and digital pin 5, respectively (Figure F).



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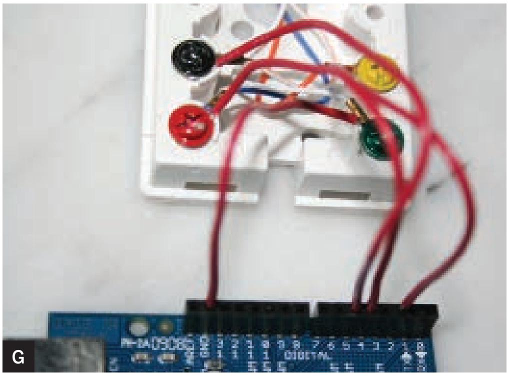
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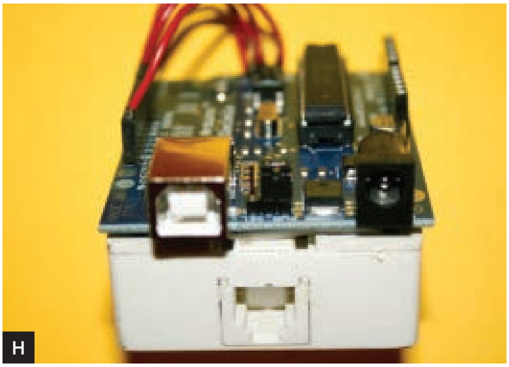
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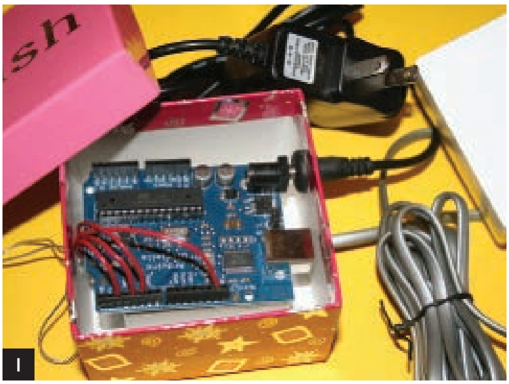

I

MATERIALS

Arduino Diecimila or Duemilanove microcontroller board
RJ11 phone jack, adhesive wall mount
Wire, 20 gauge, 12"
9V power supply aka adapter or wall wart
X10 Pro PSC05 2-way transceiver or equivalent X10 TW523
RJ11 phone cord, 3'
Decorative box, 3"×3"×3", with removable top I used a jewelry gift box.
Rubber grommets, ⅜" diameter (2)
Rubber bumpers (4)

TOOLS

Wire cutters and strippers
Screwdriver, Phillips head, small
Drill with ⅜" drill bit
USB cable

START

ASSEMBLE THE HARDWARE

To break out the four RJ11 jack contacts on the PSC05 for connection to the Arduino, I plugged in a short phone cord, plugged the other end to a wall-mount phone jack receptacle, removed the receptacle cover, and wired the receptacle contacts to the Arduino headers using 3" lengths of 20-gauge wire (Figure G). Assuming standard phone wire color-coding, connect yellow to Arduino pin 2, green to GND, red to pin 4, and black to pin 5.

Mount the RJ11 receptacle onto the back of the Arduino using the double-sided adhesive patches that came with the receptacle (or double-stick foam tape), and snap or screw its cover back on, making sure the wire connections route nicely (Figure H). Your macro module is complete; now we'll package it.

Place the module in your box and mark good locations for the phone cable and power cord to run through one side of the box, to plug into the phone receptacle and Arduino.

Drill ⅜" holes at the marked locations (after removing the module). Thread grommets over each cable, run the cables into the box, and push the grommets into the holes. Replace the module and plug in the cords (Figure I).

For a finishing touch, add rubber bumpers to the bottom of the box (Figure J, following page).


J

K

It looks so good housed in a small jewelry box that my wife allows it to reside on our bedroom dresser.

INSTALL THE SOFTWARE

Download and install the Arduino IDE (integrated development environment) software from arduino.cc/en/Main/Software, and if it doesn't include a USB serial driver for the onboard FTDI chip, download and install the latest driver from ftdichip.com/drivers/vcp.htm. Launch the IDE and select your Arduino board type under the Tools → Board menu.

Download Creatrope's X10 send/receive library from makeprojects.com/v/30 and copy the X10 folder to your Arduino libraries folder, the *Contents/Resources/Java/libraries* subfolder under your Arduino application folder (to navigate to the libraries folder, right-click on your Arduino application and select Show Package Contents). The X10 folder should now sit alongside *EEPROM*, *Ethernet*, and other included library folders.

TEST AND PROGRAM

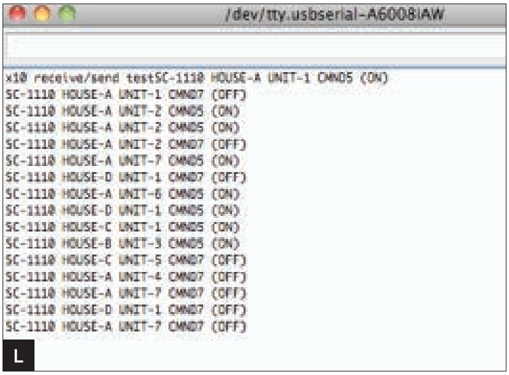
Now comes the acid test: checking the Arduino's X10 send and receive functions. Disconnect and remove the macro module from its box, and connect a USB cable between it and your computer. If you use a Diecimila, ensure that the plastic jumper near the square USB port is positioned on the 2 pins closest to the port, to supply power to the Arduino (this is not necessary with a Duemilanove). Connect a phone cable between the module's RJ11 jack and the PSC05, and plug the latter into a wall outlet.

Restart the Arduino IDE and load the *X10_receive* example code by selecting it under the File → Examples → X10 menu (Figure K). Click the Verify button at the far left of the Arduino IDE menu bar, wait for the *X10_receive* code to compile, and then click the Upload button.

Open the Serial Monitor under Arduino IDE's Tools menu. If you've done everything properly, commands and status messages from any X10 hardware you've plugged into your power line will appear in the Serial Monitor (Figure L).

We have reached the really fun part, where we exercise the Arduino assembly as a true X10 macro module. To begin, replace the `loop` function in the checkout example with new code that listens for macro triggers on the power line and responds by sending a sequence of X10 control commands. Figure M shows an example, and you can download the full C++ sketch at makeprojects.com/v/30.

Open, compile, and upload it (or a variant) to your board from your computer as you



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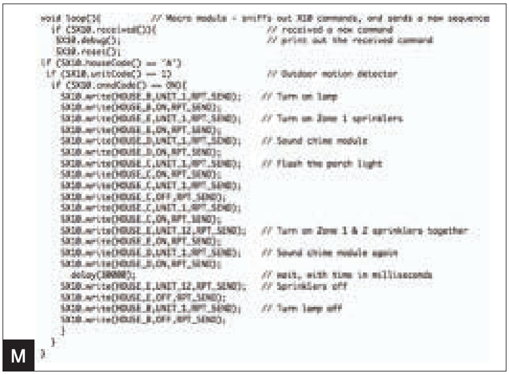


M


N

did with the *X10_receive* code earlier, then reconnect the module to power and the PSC05. The macro module will begin code execution immediately, waiting for the proper X10 trigger before performing its magic.

This powerful macro sequence controls an outdoor motion detector (set to address A1), lamp module (set to B1), light switch module (C1), PowerHorn siren (D1), and IrrMaster sprinkler controller (E12). You can buy the sprinkler controller from homecontrols.com and everything else from X10.com.

The macro example waits for a signal from the motion detector, and then responds by turning on a lamp, sounding a siren, flashing the porch light, and activating sprinklers — to scare away raccoons and other intruders. After 30 seconds, the sprinklers and the lamp are turned off.

MAXIMIZE YOUR MACROS

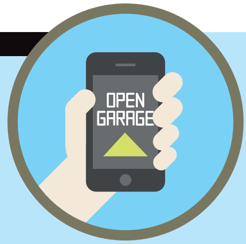
If you've done any programming, even if you're not a C++ whiz, you should be able to understand the event catcher loop code in Figure M, following the conditional phrase `if (SX10.received())`, and alter it to suit your needs. You will typically use `if` and `==` conditionals to check the X10 events received, the `SX10.write` function to send the messages that result, and the `delay` function to invoke wait periods. But of course, you have the entire C++ language at your disposal.

For instance, you can have the macro module sniff the power line for an indoor motion detector signal, and then turn on a series of lights that illuminates a path to the bathroom. This example is also included in the project code at makeprojects.com/v/30, showing how multiple macros can coexist in the same Arduino sketch.

That's about it. Reading the project code will give you a sense of how easy this really is. The possibilities for automation are limited only by your imagination.

Jim Newell (jamesmnewell.com) is an engineer/physicist at the NASA Jet Propulsion Laboratory in Pasadena, Calif.

12,000-Mile Universal Remote



Flip any switch from your smartphone!

BY JORDAN HUSNEY

Shortly after I moved into my home, my automatic garage door opener broke. For years after, I was content opening my garage manually, but last summer my contentment was interrupted by a door spring failure. When the repairman came to fix the spring, he noted that the automatic lift was also not working and offered to fix that too.

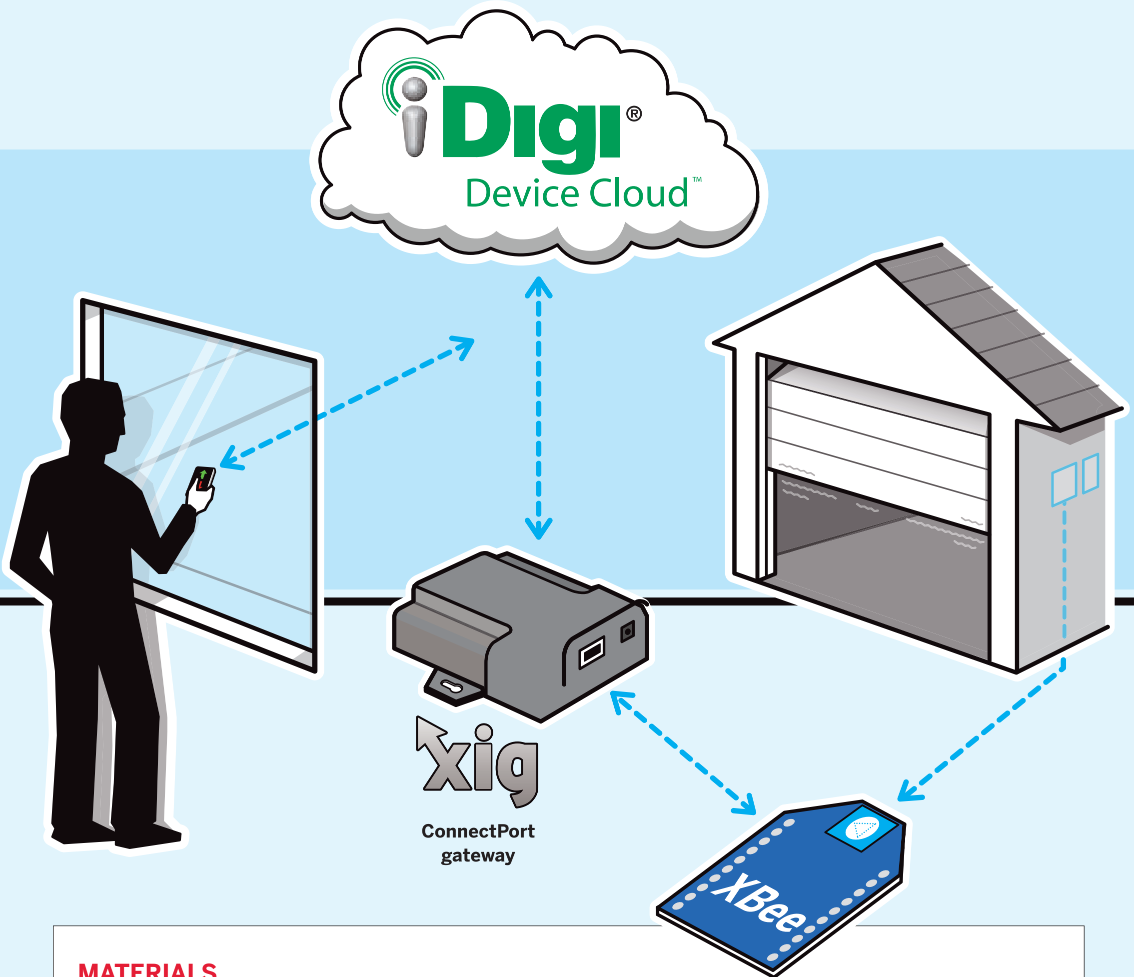
Before the repair I would simply open the door by hand, grab my bike, and ride away. After the repair I found myself needing to remember where I left the garage door remote. I fumbled in my pockets for my keys, but instead found my mobile phone. It has a radio, it can communicate with the world, and it's always with me. Why do I need a second device? I don't, and neither do you. In this project you'll learn how to connect a mobile phone, via the internet, to actuate your garage door button using a wireless mesh network.

The project has 3 parts: controlling the garage door, connecting it to the internet, and configuring the smartphone. The basic pattern you'll learn here for making your own wireless home automation devices — using Digi International's XBee radio module, ConnectPort Ethernet device, XBee Internet Gateway software, and iDigi Device Cloud service — can be used to automate countless other devices in your home. (Full disclosure: I work for Digi.)

Perhaps you'd like to know when Tiger's water bowl is empty? Detect freezing pipes or a leak in the basement? Know when the washing machine has finished its cycle? You can easily add another XBee to your network and reuse your entire wireless home automation infrastructure — the ConnectPort, XIG, and connection to iDigi. Everybody can share!

HOW IT WORKS

Almost all automatic garage door openers have a hard-wired button that when pressed opens the door. To remotely control the door, all that's needed is a simple circuit that can simulate this button press. Since you'll be able to control the door from anywhere, you'll also want to detect and communicate whether the door is open or closed. For this, you'll add a simple magnetic reed switch sensor that will tell you when the door is fully closed. Then you'll connect this circuit to an XBee radio that will allow you to wirelessly communicate with a network inside your home.



Damien Scogin

MATERIALS

Digi ConnectPort X2 gateway (XBee to IP) from Digi International #X2-Z11-EC-A (digi.com) or SparkFun Electronics #10569 (sparkfun.com)
DC power supply, 7.5V–9V such as SparkFun's wall wart #TOL-00298
DC barrel jack adapter such as SparkFun #10288
Solderless breadboard and prototyping wire
XBee breakout board for breadboarding, such as SparkFun #BOB-08276
Electrical tape or heat-shrink tubing
Wire, insulated, 16 gauge enough to run from your circuit board to your garage door lift and also to the door itself
Ethernet cable
Mobile phone, internet-enabled; or web browser
XBee Pulse I/O Board v3 (optional) For a permanent build, get our custom PCB from BatchPCB #81282 (batchpcb.com) for $23, or make your own from the CadSoft Eagle files at jordan.husney.com/xbpio.

Get all of the following breadboard build components with the $40 Digi-Key Electronics kit #6843976-KIT-ND (digikey.com), or see the full bill of materials at goo.gl/Lue81 for individual part numbers.

(The permanent PCB build requires additional components; get Digi-Key kit #6811380-KIT-ND instead, about $50, and see goo.gl/5vnSP for that bill of materials.)

Electronic components:
XBee ZB low-power ZigBee radio module with wire antenna Digi #XB24-Z7WIT-004, formerly known as XBee Series 2 module
74H123 timer chip, 16-pin DIP such as Digi-Key #296-9171-5-ND
Voltage regulator chip, LDO type, 3.3V, 950mA
Heat sink, clip-on, TO-220 type
Capacitors, ceramic: 10μF 50V (1), 0.1μF 50V (2)
Capacitors, aluminum: 10μF 100V (1), 22μF 100V (1)
Resistors, ¼W: 180Ω (1), 10kΩ (2)
Diodes, 1N4148 type (2)
Transistor, NPN, 200mA
Relay, SPDT, 1A 3V
Switch, micro tactile, SPST normally open, 50mA 24V
Switch, magnetic proximity (door closure sensor), SPST normally open, 300mA 30V, with matching magnet such as Digi-Key #CKN6004-ND
LED, 3mm, green

TOOLS

Wire strippers and wire cutters
Multimeter (optional)
Soldering iron and solder (optional) if you're making the permanent build

The XBee ZB radio module (aka Series 2) speaks the ZigBee protocol. ZigBee is great for home automation projects. It's secure and inexpensive but most importantly it's a *mesh network* — a network that can extend its range using other radios intelligently and automatically. For example, if your garage is too far away from your gateway you can simply add another radio in the middle to facilitate the wireless connection.

To connect to your garage door circuit from the internet, you'll use Digi's ConnectPort X2 ZigBee-to-Ethernet gateway. The ConnectPort X2 can be programmed using the Python language. We used an open source Python application called the XBee Internet Gateway (XIG) to create the link between our garage door and the internet. You could also connect an XBee to a PC in order to make this link, but the ConnectPort X2 uses a lot less electricity and is always ready, so you won't have to worry about forgetting to start a PC application in order to connect to your garage door. (If you wish to explore using the PC version, visit code.google.com/p/xig.)

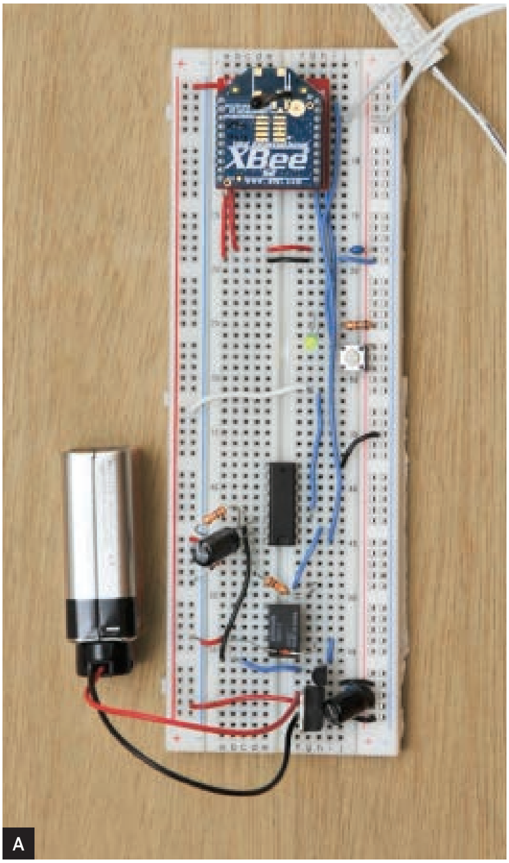
Finally, you'll set up your mobile phone to communicate with your garage door from anywhere in the world. Scott Kilau created a beautiful open source Android mobile application, and Margaret McKenna created a web version that people can use to turn any smartphone into a garage door remote.

START

1. BUILD THE XBEE PULSE I/O DEVICE

For this project my collaborator Andy Warner and I created a simple electronic device to use for all kinds of automation and monitoring tasks. It simulates pressing and releasing a button, and it also routes inputs and outputs to an XBee radio. We call it the XBee Pulse I/O. It's open source hardware: use our design, improve it, sell it to your friends, or give it away to win over your enemies.

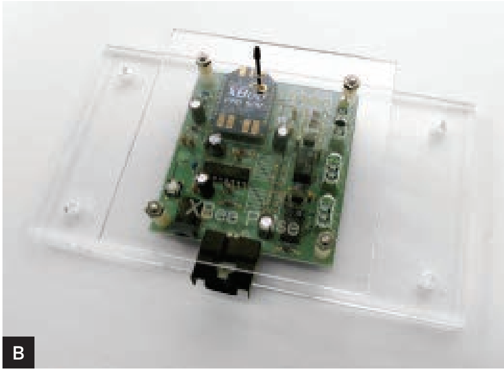
For a weekend project, you can build the device on a solderless breadboard (Figure A), using a small XBee breakout board to adapt the XBee pins to the breadboard's 0.1" spacing. Just follow the instructions and schematics online at makeprojects.com/project/x/1871 and check the materials list at goo.gl/Lue81. This is a simplified design that's intended for prototyping, not permanence.



A

Gregory Hayes

For permanent installation, we recommend using our custom printed circuit board (PCB), the XBee Pulse I/O Board (Figure B), which is described at jordan.husney.com/xbpio. It's open source too — feel free to make your own. For security it adds static protection on the sensor inputs, and a circuit that stops the garage door from being toggled in the event of a power outage. Assembly is simple: find an empty spot on the PCB and note its silkscreen label (e.g., capacitor C6). Locate each item in the materials list online and solder it in place, taking care to orient it correctly. Don't solder down the XBee module — use the 10-pin headers, so you can remove it if you wish.



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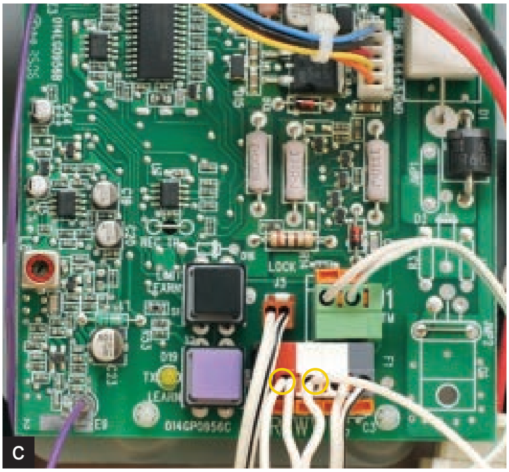


C

CAUTION: Take care not to tap the 110V wiring that powers the door; it's dangerous!

When you release it, the lift should activate.

If the door doesn't activate, you'll need to work your way through each possible pair of connections until you find the one that works. You may find a multimeter useful in your search: set it to measure AC voltage (up to 24V) and probe between each pair. You should be able to find a wire that always registers a voltage when compared against any other wire: this is the ground wire. Test by shorting between the ground wire and the other wires until you find the one that activates the door.

Now connect your XBee Pulse I/O circuit to the door lift by connecting the common wire and the normally open wire from the relay output to the 2 garage door lift wires. It doesn't matter which goes to which. When the relay activates, it will momentarily short the 2 lift wires together, simulating a button press.

2. CONNECT THE XBEE PULSE I/O TO THE DOOR LIFT

At least 2 wires will connect your door opener button to the lift. Use a ladder to see where these wires attach to the lift. If you're lucky they'll attach to screw terminals. If you're unlucky they'll go directly inside the lift, and you'll need to tap into their connections inside (Figure C), or else strip a little insulation away from each wire leading into the lift in order to tap into them. Take care not to sever the wires as you strip them, and patch them up with electrical tape when you're finished.

Cut a 6" length of wire and strip both ends. Connect it between the 2 screw terminals or internal contacts, if you have to tap into the wires, between the 2 wires themselves. Only hold the connection for a half second or so.

3. CONNECT THE INTERNET GATEWAY

Now that we've got our XBee Pulse I/O installed we've got to be able to reach out and talk to it remotely. This is a harder problem than it appears. For one, our mesh devices don't have IP addresses. For that, we need to connect them to an IP-to-ZigBee gateway. We also need to make the gateway accessible to the world. Before, we'd have to create a special rule on our home router to allow incoming traffic and then remember our home IP address — and worry about it changing. Fortunately there's a better way.

The Digi ConnectPort X2 gateway creates a connection from our house to a special free service called iDigi. This connection acts like a secure tunnel back to the gateway in our home. Using the proper credentials, remote applications can talk to iDigi and pass information all the way to devices on our mesh network. So why use a dedicated gateway and not a PC? For the same reasons we use wi-fi routers instead of PCs set up for internet sharing: simplicity, reliability, cost, and efficient power consumption.

First, connect your ConnectPort X2 gateway to your internet connection by plugging it into a spare Ethernet port on your switch or router.

Jordan Husney (B)

Open a web browser and go to idigi.com. Click the Get Started Now button and create an account on the iDigi Developer Cloud (a free version of iDigi Device Cloud that allows up to 5 devices). Once logged into iDigi Manager Pro, go to the Devices page and click the Add (+) button. The application will look for the ConnectPort X2 on your local network (Figure D). Once it's found, click on it to select it, and then click Add. After a minute, click Refresh and you'll see your ConnectPort X2 listed as "Connected." This means the gateway can talk to the world, and the world (if it has the proper credentials) can speak to your gateway and devices.

Power up your XBee Pulse I/O, right-click on ConnectPort X2 on the Devices list, then select Discover to add your XBee radio node to the list too.

To control how the gateway speaks to the world, you need to load some extension software onto it. The XBee Internet Gateway (XIG) is a Python program that allows our mobile phone app to send remote commands to open and close the garage door. It also streams SSL-encrypted sensor information from the XBee Pulse I/O to the iDigi service, which allows our mobile app to know whether the door is open or shut. That's neat!

Download XIG version 1.4.0 or newer from code.google.com/p/xig, and unpack the archive into a folder on your desktop.

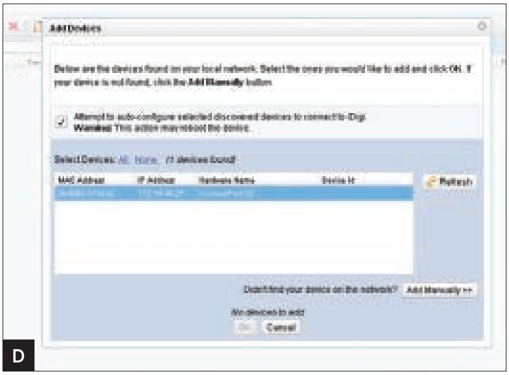
Log into the iDigi Developer Cloud, go to the Devices page, double-click on your gateway, and select Python from the list of configuration sections. Click the Upload icon, browse to your unpacked XIG files, and upload all files except the software license and *README* file. Once the upload completes, type `xig.py` into the Auto-start Command Line field and check the Enable checkbox. Close the configuration pane, right-click on the gateway, and select Administration → Reboot. Your gateway is all configured!

4. CONFIGURE YOUR MOBILE PHONE

Now for the easy part. If you have Android, install the XBee Garage Door application from the Android Market (market.android.com). Start the app and enter your iDigi Developer Cloud username and password. You'll be prompted to select the correct gateway and XBee node.

If you've got a different web-enabled phone, then use the browser interface at xbee-garage-door.herokuapp.com.

Now test the door closure sensor. If you place the magnet next to the sensor, the contact will close. After a few seconds the state change will be transmitted all the way from the XBee, through the gateway, to the phone app or web interface, via iDigi (Figure E).

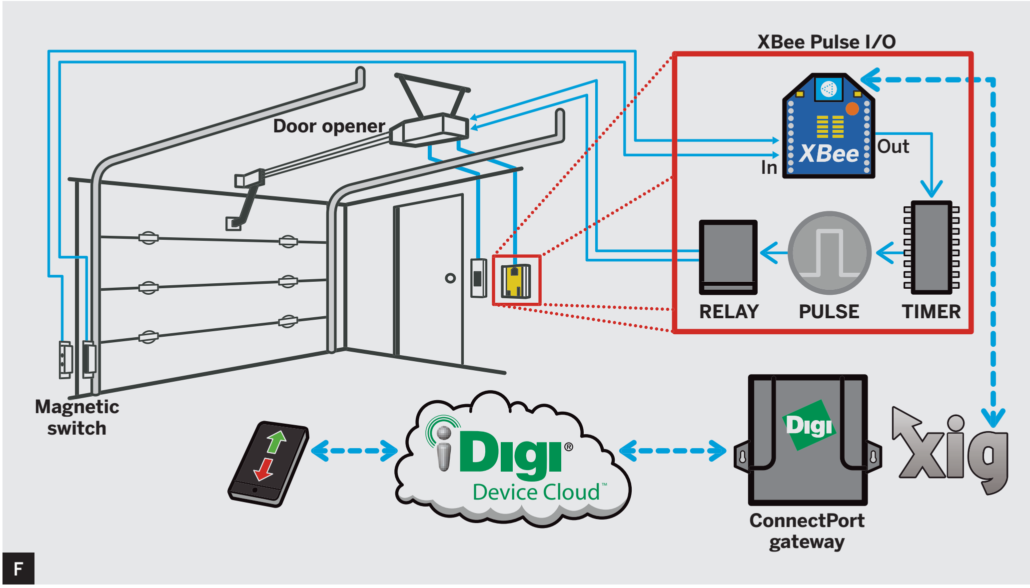


D

E

5. MOUNT THE DOOR SENSOR

Carefully disconnect the magnetic door sensor



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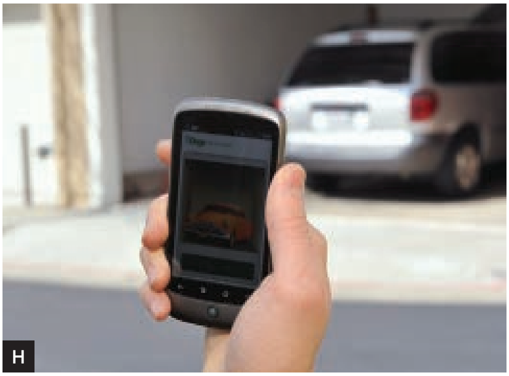

H

from the XBee Pulse I/O. Close your garage door — hey, use your phone! — and choose a location to mount the sensor on the wall alongside the door, 4"–6" from the ground. Mount the magnet on the door itself, opposite the sensor and close enough that the sensor can detect the magnet (Figures F and G).

Now just by pressing the button in the Xbee Garage Door app on your phone (Figure H) you'll be able to open and close your garage door ... like a boss!

TAKE IT FURTHER

You can easily adapt this system to press any button in your house, from anywhere. Start your mixer to terrify your cat. Turn on your yard lights to welcome your kids home. Ring your own doorbell!

After you build something cool, please tell us about it on the XIG project website (code.google.com/p/xig).

For schematics, breadboard instructions, and video, see makeprojects.com/v/30. For parts lists, troubleshooting, and source code for the web browser interface, see jordan.husney.com/xbee_garage_door.

Jordan Husney is a Digi technologist and designer interested in making it easy to connect anything to anybody anywhere. He was technical editor on *Building Wireless Sensor Networks* by Robert Faludi. He can frequently be found rock climbing or barbecuing up a storm.

Damien Scogin (F)

Keybanging

Enjoy code-free home automation using prop controllers.

BY WILLIAM GURSTELLE

Despite the unfortunate experiences of Dr. Frankenstein, I think adding life to inanimate things is one of most interesting types of automation. Thanks to the current generation of easy-to-use programmable animation controllers, making an articulated figure move like a person, giving jets of water "personality" as they stream out of a fountain, or sequencing holiday lights to musical beats isn't just for theme park set designers anymore.

Of course, making all that happen requires computer programming. I may be limiting my opportunities to tackle the most involved projects, but I don't want to be a computer programmer. If a project includes stuff like:

```
void setup(){ pinMode(ledPin, OUTPUT);
```

then count me out.

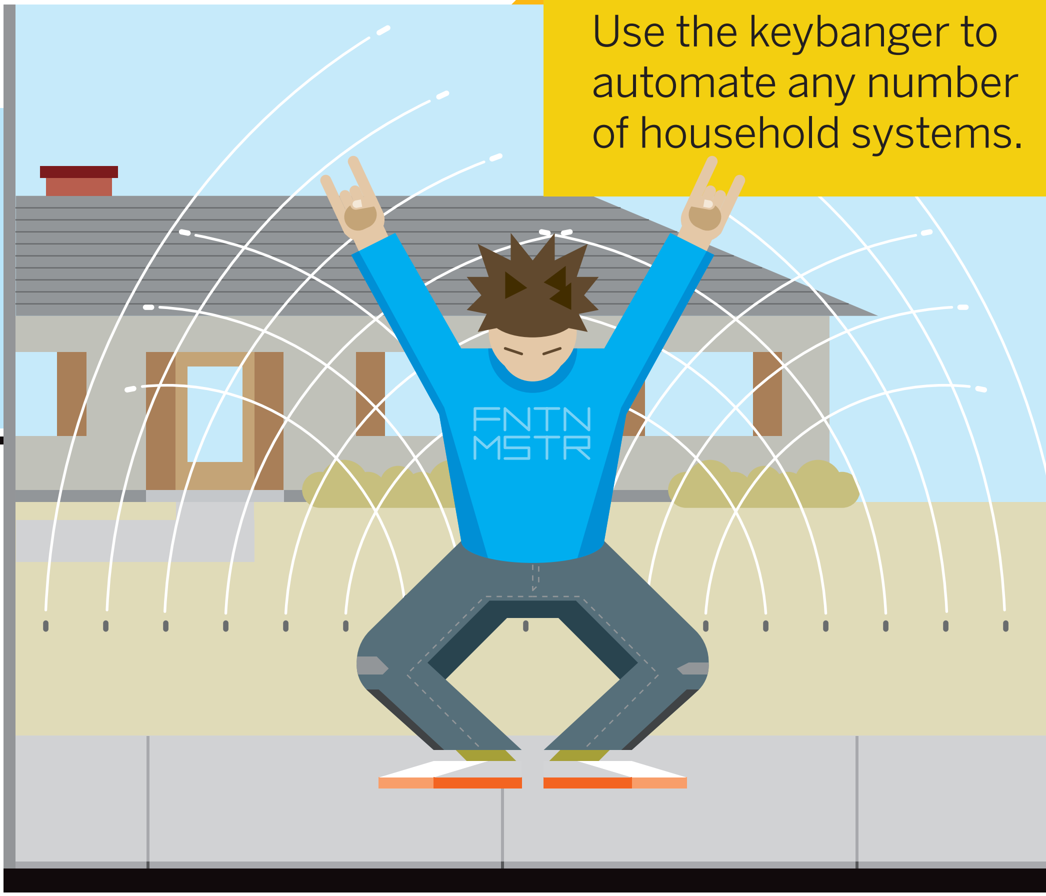
Sure, microcontrollers like Arduino and BASIC Stamp can perform a million automation tasks a million different ways, but usually that's overkill for what I need. Instead, I use a far simpler method of adding life to props, displays, and room environments that doesn't require coding or digital programming.

It's called *keybanging*. A keybanger is a standalone, controllable programming device that allows the automation of complex tasks through a simple pushbutton programming interface. Born in the animatronics industry, these devices are also known as *prop controllers*, *programmable switches*, or *effects programmers*. The simplest devices have a single trigger circuit, control a single device, and cost about $50. More elaborate models use a microcontroller chip for a brain and include onboard audio amplifiers, output relays for 8 or more devices, interfaces for servomotors, and (shudder) a programmable digital interface to supplement the buttons.

Besides animatronics, keybangers are used to automate water fountains, fireworks, lighting displays, sound systems, slide and movie projectors, window displays, signs, or just about anything else that can be controlled by an electrical on-off signal.

Say, for example, you had a 6-pump water fountain and you wanted to coordinate the fountain sprays to the rhythm of a particular piece of music. If you used a typical microprocessor, this would require some elaborate I/O programming. Further, turning the water jets on and off to coordinate with the music equates to some fancy sequencing and timing.

But programming a keybanger for this job is quite simple. Just play the music and then push the buttons when you want the foun-



Use the keybanger to automate any number of household systems.

tains to spray; release them when you want them off. All keybangers allow you to record at least a 2-minute-long sequence, and some allow for far longer programs.

Input/output schemes on keybangers are straightforward. There are one or more trigger inputs on the front of the box. When the circuit is closed (or opened, depending on the type of trigger) the device begins running its program. The circuit closure could be a simple pushbutton, a switch hidden under a floor mat, or a passive infrared sensor, for example. When the circuit closure is made, the keybanger detects it and starts running its program.

Once the program starts, electrical contacts on the device open and close according to the instructions you programmed into it. When the keybanger is triggered, its little computer brain turns the attached gadgets on and off in accordance with the program. Since the unit is fairly intelligent (at least in a specialized way), it can easily control complicated or lengthy sequences.

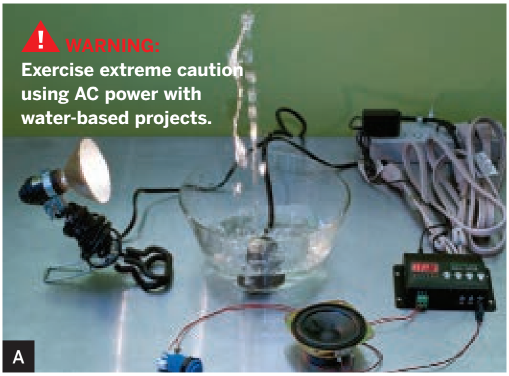
A number of small electronics designers produce keybanger logic systems. An internet search will turn up dozens of websites with products made by companies ranging from part-time garage operations to large companies with customer support staff and full product lines. Most, but not all, started in the commercial haunted house business. In fact, animating Halloween props is by far the most common application.

The simplest and cheapest devices sequence a single relay. A well-known device of this sort is the Animation Maestro from Haunted Enterprises. AMs are great for simple Halloween props such as the beloved Trash Can Trauma (see MAKE's Halloween

L-Dopa

MATERIALS

Prop controller, Monster Guts Nerve Center Other controllers would work equally well; however, you may need a separate amplifier to drive the speaker.
Speaker, 8Ω Use one with a ⅛" phono plug to connect to the Monster Guts Nerve Center.
Switch, momentary pushbutton, normally open (NO)
Fountain pump, submersible
Water container
Light source such as an incandescent bulb, LEDs, etc.
Extension cords, 6' (2)
Wire, miscellaneous
Digital music player (e.g., iPod)



A

B

Special Edition from 2007, makershed.com item #HALLOW07.) An Animation Maestro costs about $60. The simplest model has a single trigger input and a single output. Programming the device takes about a minute to learn.

Gilderfluke & Co. designs and manufactures a wide variety of animatronic devices. Their MiniBrick controller models can control 4, 8, or 32 relays, and can interface with standard DC servomotors. As keybangers go, MiniBricks are the most complicated to program, but once you figure out the nuances, their capabilities are nearly endless. An 8-output MiniBrick with 2 servo outputs runs $210.

My personal favorite is the Monster Guts Nerve Center for about $70. The Nerve Center controls 2 on-off relays and has a small LED display that makes it a snap to program. It runs multiple programs, so the animation can behave differently on successive triggers. Best of all, it has an onboard audio amplifier and enough memory to record 8 seperate sound tracks, so if your project includes sound, just add a speaker (no amp needed) and you're good to go. Here's how I used it to make an animated water fountain.

START

1. BUILD YOUR FOUNTAIN TABLEAU

Place a submersible fountain pump inside a water-filled container and plumb the device so that the water jets upward when the pump is energized. Attach a light source to the container so you can light up the water spray (Figure A).

2. SET UP THE AUDIO

Connect a music source (e.g., iPod) to the audio input on the Nerve Center, and connect a speaker to the audio out jack (Figure B).

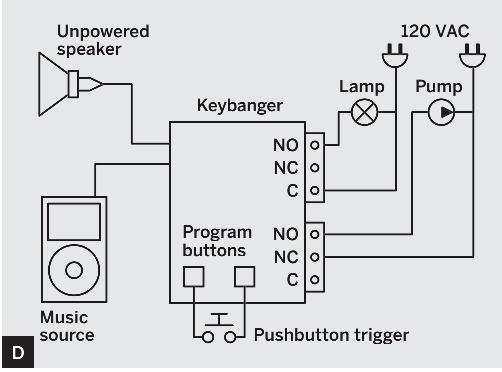
Select the Enter Sound command and record your musical selection into memory.

3. CONNECT THE PUMP AND LIGHT

The Nerve Center connections are simple

Gregory Hayes


C



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F

relays that make or break according to the programmed instructions. The Nerve Center doesn't provide AC power; it merely switches it on or off. That means that to control power to the pump and light, you'll need to break into one conductor on each extension cord so they connect to the Nerve Center relays (Figure C) as shown in the schematic (Figure D).

4. RECORD YOUR SEQUENCE

This is the fun part. Select the Action Control command on the LED display. The music recorded to the device in Step 2 begins to play.

Use the 2 programming buttons on the front of the controller to bring your fountain to life. When you depress the button corresponding to the pump, the pump will run. Releasing the button will turn it off. The light control button works similarly. You can sequence your entire show just by pressing and releasing the 2 buttons on the front panel (Figure E). The fountain spray and light work independently, so you can devise all sorts of routines.

5. ADD A PUSHBUTTON

Wire the pushbutton switch between the keybanger's NO (normally open) and Common trigger contacts (Figure F).

6. ANIMATE!

Select the Scene Control command and press the pushbutton to trigger your animated sequence. Want to make changes? Just tweak the program for best effect, then sit back and enjoy the show.

The applications for keybangers are limited only by your imagination. By replacing the pushbutton with a sensor (motion, heat, humidity, temperature, etc.) you can use the keybanger to automate any number of household systems. If you come up with a good application for a keybanger, head over to makeprojects.com and share it with the readers of MAKE.

William Gurstelle is a contributing editor of MAKE. Visit williamgurstelle.com for more information on this and other maker-friendly projects.

HOME SMART HOME

THIRSTY TWINKLING

The number one killer of potted plants is overwatering — especially in shared spaces where several people may be watering them. Hanging Gaerden, a collaboration between the designers at Manchester-based The Clorofilas and Barcelona-based Aer Studio, helps prevent involuntary herbicide with a communication system of twinkling LED lights. The LEDs are hooked up to moisture sensors in the soil of the potted plants, and when moisture levels get too low, the light animation rhythm increases, making them hard to ignore. makezine.com/go/hanginggaerden

—Laura Cochrane

YOU'VE GOT (SNAIL) MAIL

When MAKE contributor Matt Richardson wanted to bring a little digital to his analog, he devised the clever Snail Mail Push Alerts system to receive iPhone push notifications when the mailman made a delivery. Richardson made it using an Arduino paired with an Ethernet shield, a snap action switch installed under his mailbox, and an iPhone app called Prowl. Check out his video project guide to bring your mail into the 21st century. makezine.com/go/snail

—Goli Mohammadi

SUPER HOUSE

Far from the home of the future, Melbourne, Australia's Jonathan Oxer has built the maker home of today. Lights, curtains, fans, and more are wired to three switchboards with Arduino-compatible microcontrollers with built-in Ethernet, though manual switches still function. A Linux-based hub connects it all together and allows Oxer to input commands through his Android phone or an Android-based touchscreen interface, and even control a few things with gesture commands through a Kinect box. superhouse.tv

—Craig Couden

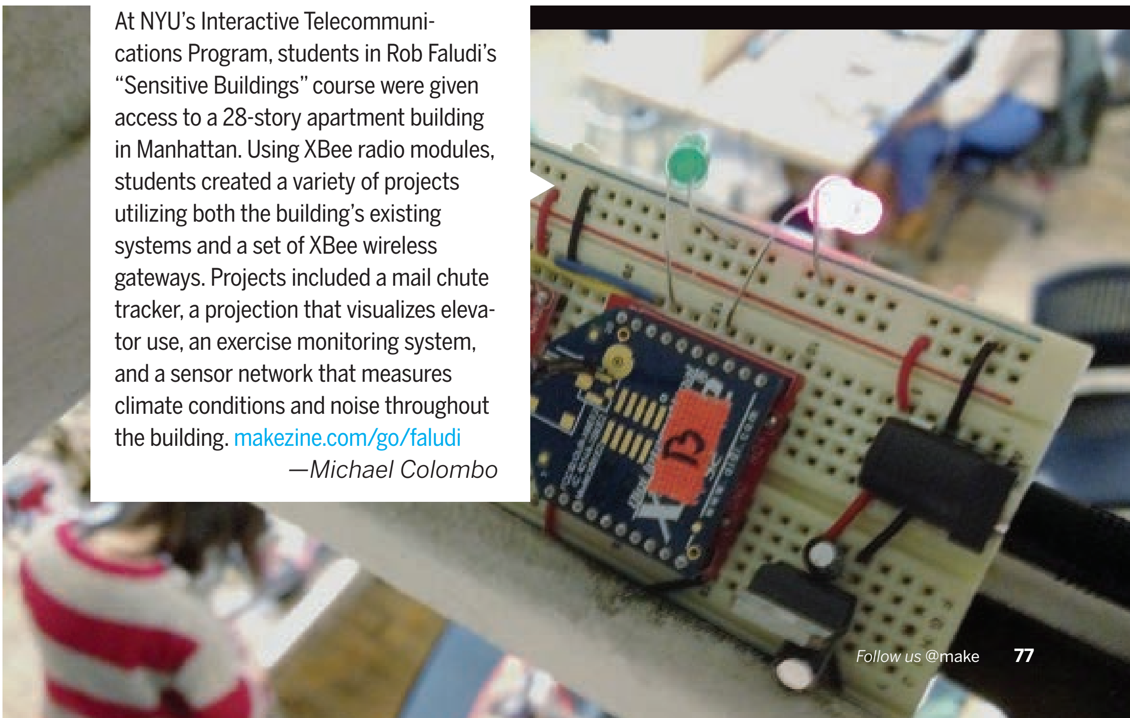
PHONE HOME

Mi Casa Verde's latest home controller, Vera 3, is a Linux-based wi-fi router that works with Z-Wave, Insteon, and X-10 protocols. Connecting Z-Wave devices works much like Bluetooth pairing, and MiOS support puts it all on your smartphone. Third-party apps bring extra functionality, like enabling cameras for remote live streaming video, and open APIs allow users to flex their imagination and coding skills. micasaverde.com *—CC*

SENSITIVE BUILDINGS

At NYU's Interactive Telecommunications Program, students in Rob Faludi's "Sensitive Buildings" course were given access to a 28-story apartment building in Manhattan. Using XBee radio modules, students created a variety of projects utilizing both the building's existing systems and a set of XBee wireless gateways. Projects included a mail chute tracker, a projection that visualizes elevator use, an exercise monitoring system, and a sensor network that measures climate conditions and noise throughout the building. makezine.com/go/faludi

—Michael Colombo



Joe Armao (Super House)

IS IT HOT IN HERE?

Futura Elettronica, based in Italy, has developed the TiDiGino GSM remote, based on the popular ATmega2560 chip. With two relays, an onboard temperature sensor, and two optocoupled inputs, you'll be able to monitor your home's temperature and receive SMS alerts to your phone when temps fluctuate. Hardwire it directly into your household temperature control and remotely turn it on/off via your phone. Compatible with standard Arduino shields and programmed via the Arduino IDE with sketches and libraries, the remote ships from the UK at about $155 USD. makezine.com/go/tidigino

—Nick Raymond

GEEKED OUT GARDENING

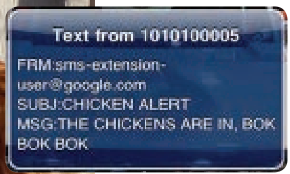
What do you get when you mix Arduino and an indoor garden? Garduino, of course. Luke Iseman was interested in gardening but knew he couldn't keep up with the daily watering and lighting requirements, so he put his tech to work. Combining an Arduino and a series of inexpensive sensors (photocell, thermistor, and galvanized nails), his system ensures the plants get watered when they're thirsty and get light when they need it, and it alerts him when temperatures drop. makeprojects.com/project/g/62 *—GM*

YOUR TV REMOTE IS SO 20TH CENTURY!

For a quick and dirty home automation tool to impress your friends, try the SQ Blaster Plus to control your home theater with your iPhone or iPad. The Blaster Plus connects to your devices through your home wireless network and then "blasts" an IR signal to your home entertainment setup. It works like a universal remote, and for an extra $30 you can design and trick out your own iPhone/iPad user interface.
squareconnect.com *—CC*

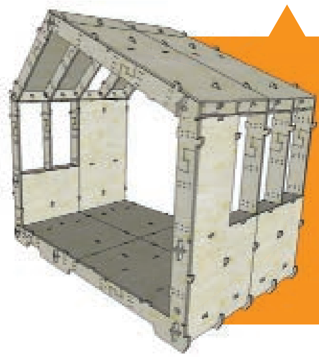
FOR THE BIRDS

Wanting to make his low-maintenance chickens even lower maintenance, Alan Graham devised an automated henhouse in his garage with an infrared motion detector, automatic lights, a heater, and an automated door. Graham gets text alerts when the ladies get out in the morning and when they come back in at night. Check out his build instructions, where he shows how to rig the system with a computer or without. makeprojects.com/project/a/1450 *—GM*



MI CASA ES SU CASA

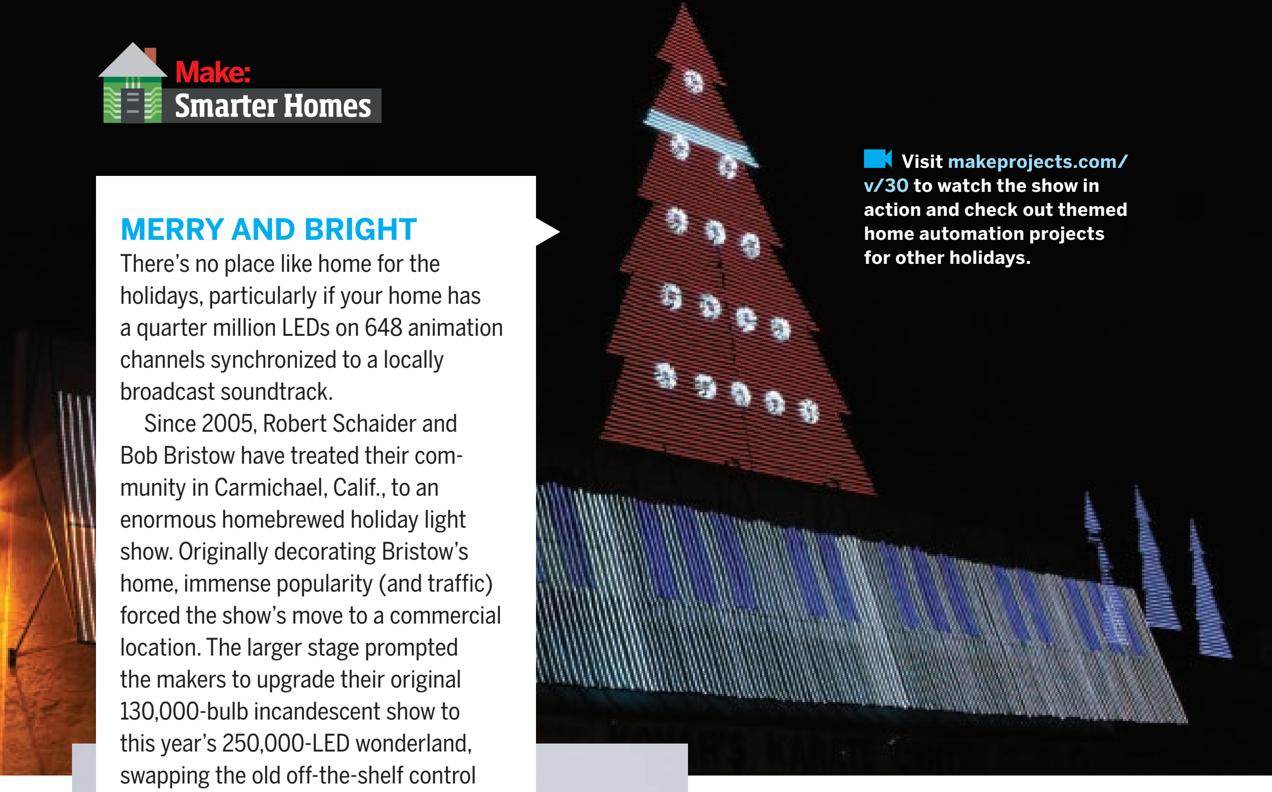
WikiHouse is an open source construction set: a pool of 3D models of houses and a plugin to help convert them into CNC cutting files, shared under Creative Commons. The WikiHouse SketchUp plug-in turns 3D models into labeled 2D milling sheets that can then be cut on a CNC and put together, like a very big piece of flat-pack furniture. The plug-in script is available on Github for others to build on and improve. wikihouse.cc *—LC*



Design, download, and 'print' CNC-milled houses.

TAPROOM

Michael Meyer has the right idea when it comes to home automation and drinking beer. Using a chest refrigerator as the base for a three-tap bar, Meyer brought the taproom to the living room. The configuration chills three 5-gallon kegs and uses a Dwyer Love TSS2 temperature controller and two temperature probes to monitor the two-stage system and minimize foaming in the beer lines. Complete with IR remote to set the mood lighting with multicolor LEDs. Brilliant! See his build photos for more ideas. imgur.com/a/n8eHd *—NR*



Visit makeprojects.com/v/30 to watch the show in action and check out themed home automation projects for other holidays.

MERRY AND BRIGHT

There's no place like home for the holidays, particularly if your home has a quarter million LEDs on 648 animation channels synchronized to a locally broadcast soundtrack.

Since 2005, Robert Schaider and Bob Bristow have treated their community in Carmichael, Calif., to an enormous homebrewed holiday light show. Originally decorating Bristow's home, immense popularity (and traffic) forced the show's move to a commercial location. The larger stage prompted the makers to upgrade their original 130,000-bulb incandescent show to this year's 250,000-LED wonderland, swapping the old off-the-shelf control system for custom software written by Bristow. Capable of 16 million colors and 48 frames/second, each LED required manual programming; each of 2011's three songs took between 40–80 hours to animate. *—Gregory Hayes*

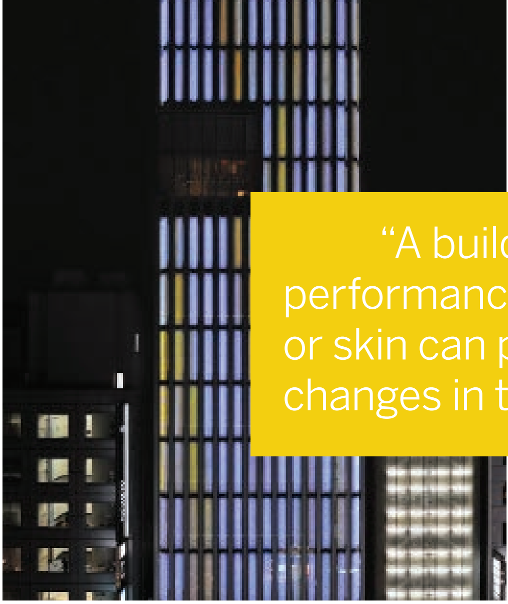
WICKED SKETCHES

The folks at Wicked Device have been hard at work on their Nanode, an Arduino clone with integrated Ethernet. The Nanode itself isn't new but they've developed a groundbreaking new system that allows you to completely reprogram your Nanode by sending Arduino sketches right over the internet.

All you have to do is hook up your Nanode, equipped with a special bootloader, to a wired internet connection and access the Sketch Garden site (sketchgarden.co) with a computer located anywhere on the globe. Then simply upload your sketch, hit the Download button, and the Nanode will automatically receive and begin to run the new program. The site uses a simple drag-and-drop interface for intuitive use and stores your sketches so they're always available.

This is perfect for Nanodes that have been deployed in the field and require software updates, or for reprogramming the Arduino-controlled thermostat at your beach house in Hawaii. You can pick up a Nanode now in the Maker Shed! makershed.com

—Michael Castor



> "A building will realize significant performance benefits if its facade or skin can physically respond to changes in the environment."

AUTOMATION FROM THE OUTSIDE IN

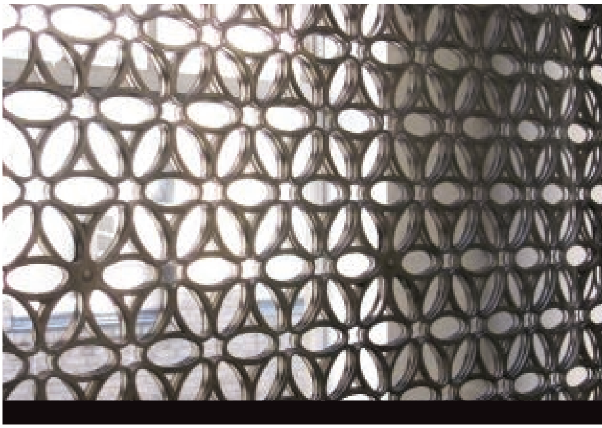
With most automation projects, all the interesting things happen *inside* the home. Lights come on. Heating systems respond. A few automated gadgets interact with the windows, like motorized blinds or skylights, but it's all controlled internally. Contrast this with advanced work being done to automate commercial buildings, where you'll see much of the action happening out of doors. After all, that's the best place to fend off solar gain and other impacts of weather.

"A building will realize significant performance benefits if its facade or skin can physically respond to changes in the environment," says mechanical engineer and designer Chuck Hoberman, who has designed several active building skins, in place around the world, that respond electronically and mechanically to the weather. Hoberman's name might be familiar to people with kids, because he's the designer of the Expanding Sphere Toy. His larger transformable designs have gone into museums over the last few years, and he was responsible for engineering the giant expanding structure that held 888 LCD screens as the centerpiece of the U2 world tour ending in 2011.

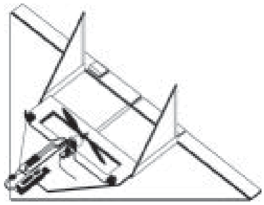
Now, partnering with construction engineering company Buro Happold, Hoberman's company has four different types of responsive building skins. His "tessellate," for example, consists of overlapping metal panels with perforations in them. As motors and actuators shift the panels' positions, the individual units become transparent or opaque, shielding a building's occupants from the sun, depending on the season and time of day. Other Hoberman surfaces have small metal plates that fan out like wings. "Each unit is individually controllable," he says, "When you install them in a field of hundreds or thousands across a building facade, then you can see it as an adaptive field. If a shadow falls across the building, you might notice a small region open up to bring in more light or see a gradient effect that sweeps across the structure."

Don't look for such advanced skins stretched across your neighborhood split-level anytime soon. Commercial construction has the scale and finances to pay for such research and development. But intelligent surfaces are certainly an idea that will catch on in residential construction in the years ahead.

hoberman.com —*Bob Parks*



Mamoru Ishiguro (top), Adaptive Building Initiative (bottom)



THE TOWEL

Build a robust R/C flying-wing airplane that's fun to fly and great to learn on.

By Breck Baldwin

The great power of the Towel is that everyone thinks they can make one — and they're right. Stupid-simple to build, all it takes is a spare afternoon, $100 worth of gear, and some DIY chutzpah.

The Towel is a great-flying airplane that's optimized for typical urban flying conditions: gusty winds, small flying spaces, and rough landing spots. Unlike store-bought beginner planes, the Towel has a 1:1 thrust-to-weight ratio that makes it highly maneuverable. This allows it to fly in tight spaces and turbulence. It can also carry a camera.

Lots of people have learned to fly on the Towel. Repairs are simple and the airframe can take a lot of punishment before needing replacement, which takes minutes. It's made from recycled materials and designed to not seriously hurt people or property.

Why the Towel moniker? Back in the day, I was flying an early version of the plane that had met Mother Earth at aggressive velocities many times. The nose had become a rumpled shadow of its former self. A fellow pilot, who was a bit of a smartass, remarked that it looked like I was trying to launch a wet towel, and the name stuck.

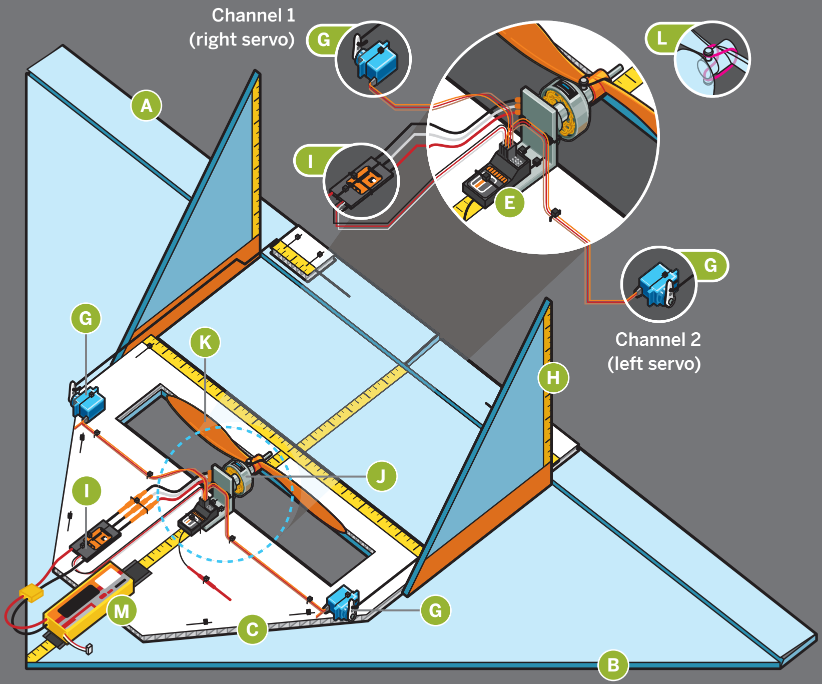
The Towel's detachable deck is an innovation in DIY hobby flying. You'll spend 80% of your build time on the deck, and only 20% on the airframe and control surfaces. This allows for a very desirable property of the Towel, which is that the airframe can be easily replaced in that 20% time frame. We can all thank Mark Harder (aka Splinter) for the deck concept.

We estimate that well over 100 Towels have been built, by kids and by vastly older kids. Here's how you can make one.

Breck Baldwin (breck@brooklynaerodrome.com) lives and works in Brooklyn, N.Y., trying to populate the sky with interesting objects. He has a Ph.D. in computer science and is the founder of LingPipe.com and chief scientist at YapMap.com.

Gregory Hayes

SET UP: p.85 | MAKE IT: p.86 | USE IT: p.94



LITTLE WING

The Towel is a *flying wing* — a fixed-wing aircraft without a fuselage or separate tail structure. Like Northrop Corp. and Germany's Horten brothers, we found advantages in its simple and strong construction.

A Flight is steered by 2 independent elevons on the wing's trailing edge, rather than the separate elevator and ailerons used in traditional planes.

B The airframe is cheap, rugged polystyrene foam that's easily replaced.

C The detachable deck holds the motors and electronics.

D The radio transmitter sends control signals on 3 channels: throttle, aileron, and elevator.

E The radio receiver relays the signals to the onboard electronics.

F The elevon mixer (onboard or in the transmitter) blends the aileron and elevator signals to coordinate the 2 elevons.

G Two servomotors move control rods to raise and lower the elevons.

H Twin vertical stabilizers help the plane track straight without yawing.

I The throttle signal governs the electronic speed controller (ESC), which provides AC power to the motor, and also powers the receiver and servos through its battery eliminator circuit.

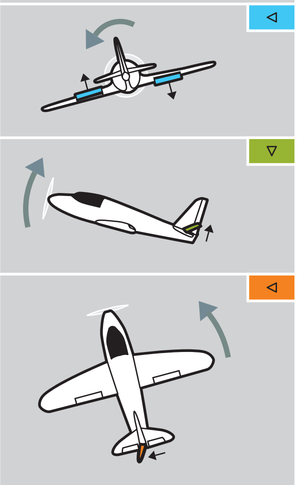
J The outrunner motor is a brushless AC motor that spins its shell around its windings, for low speeds and high torque without a gearbox.

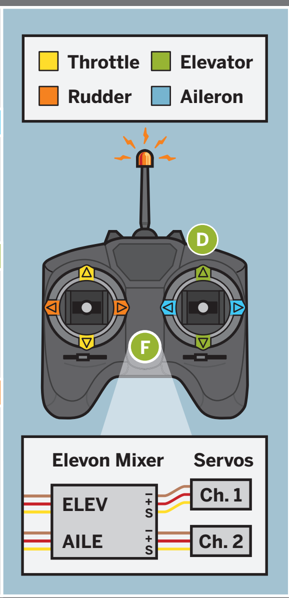
K The propeller is a reduction-drive (RD) or "slow-flyer" type. Together with the outrunner motor, it provides a powerful 1:1 thrust-to-weight ratio.

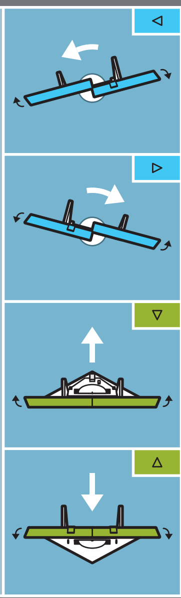
L The prop saver holds the prop on the shaft with an elastic O-ring so it can detach (not break) in a crash.

M The LiPo battery pack powers 6–7 minutes of flight. Its placement is adjusted with velcro to fine-tune the plane's center of gravity.

4 CHANNEL R/C AIRPLANE







3 CHANNEL R/C ELEVON PLANE

Most R/C planes have 3 servos, for the ailerons on the wings, the elevator in the tail, and the rudder. A flying wing has 2 servos, for each of its twin elevons, but there's no rudder. This requires *elevon mixing* by a microcontroller.

» *Aileron* signals govern *roll*. The mixer pushes/pulls the elevons in opposite directions.

» *Elevator* signals govern up/down *pitch*. The mixer raises or lowers the elevons together.

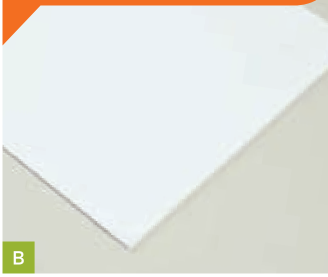
» Rudders govern left/right *yaw* in a 4-channel plane, but the Towel's big stabilizers eliminate the need for one.

Rob Nance

SET UP.

GET the KIT
coming soon from
MAKER SHED #MSFW1


A


B


C


D


E


F

MATERIALS

Coming soon: get the complete kit in the Maker Shed item #MSFW1 (makershed.com)! Download templates for the airframe, deck, and stabilizers at makeprojects.com/v/30.

A. Extruded polystyrene insulation board, fan-fold, ¼"×24"×48" We use Dow High Performance Underlayment-PP (faced with plastic film). It weighs just 4oz for the airframe and stabilizers. Ask for leftovers at construction sites. You can also use stiff cardboard, presentation board, Coroplast, or Depron foam, but heavier materials may require a stronger motor and more nose weight. Softer materials may cause flutter.

B. Corrugated plastic, 3mm, 11"×16" such as Coroplast. You can get it from recycled signs.

C. Servomotors with 17oz/in of torque (2) with servo extensions if needed. We like the HexTronik HXT900 and Turnigy TG9e servos.

D. Electronic speed controller (ESC), rated between 15A–20A, with BEC (battery eliminator circuit)

E. Motor, brushless, outrunner style, 3mm shaft capable of 15oz thrust using 2 cells (7.4V) and a 10×4.7 or 9×6 prop, such as the classic Tower Pro Outrunner 2408-21

F. R/C transmitter and receiver, 3 channels or more such as Hobby King HK-T6Av2. Check hobbyking.com for the latest. It's a dynamic market.

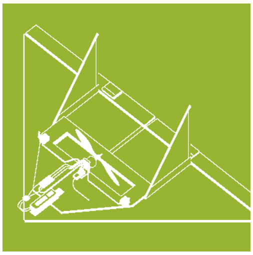
» **Propellers, GWS slow-flyer style, 10×4.7 or 9×4.7 (3)** Get a 6-pack; you'll break some. You can also use the APC slow-fly 10×4.7, but its hole is bigger and will require a different attachment to the motor.
» **Tape, double-stick, high strength, ¾"×4"**
» **Cable ties, nylon, at least 6" long × 1⁄10" (30)** aka zip ties
» **Aluminum angle, 1½"** or similar stock, to make the motor mount
» **Connectors, motor to speed controller, 3.5mm (3 pair)** We used 3.5 mm gold bullet connectors.
» **Heat-shrink tubing, 4mm, 3" length (optional)** for soldered connections
» **Connectors, battery to speed controller, 15A** Match your battery's connector, or get a male/female pair. We used 30A Anderson Powerpole here. Also good: HexTronik XT60.
» **LiPo battery pack, 2 cell, 1,500mA–2,000mA** capable of 15 amps power draw
» **Propeller saver, 3mm** or other size to match your motor and prop. If you use the larger APC props you might not be able to use a prop saver, but those are stronger props anyway.
» **Coat hangers, wire (2)**
» **Tape, hook-and-loop, ¾", 6" length** aka velcro tape
» **Tape, packing** the uglier the better
» **V-tail mixer or elevon mixer (optional)** if your transmitter doesn't have elevon mixing

TOOLS

» **Needlenose pliers with wire cutters**
» **Felt-tip pen**
» **Drill with assorted small bits: ⅛", 1⁄16", etc.**
» **Screwdriver, Phillips head, small**
» **Hex key (optional)** if needed to remove your motor's mount
» **Razor knife or box cutter**
» **Hacksaw**
» **Ruler**
» **Soldering iron and solder (optional)** if your connectors need soldering
» **Heat gun or butane lighter (optional)** for heat-shrink tubing

Gregory Hayes

MAKE IT.



BUILD YOUR TOWEL

Time: 4–5 Hours
Complexity: Easy

1. PRACTICE FLYING

While you wait for your parts to arrive, get a flight simulator. Free ones include FMS (n.ethz.ch/~mmoeller/fms) for Windows, and CRRCSim for most platforms (sourceforge.net/apps/mediawiki/crrcsim). Program your game controller to work like an R/C transmitter: up stick is down pitch. Many transmitters also have USB interfaces that can drive the flight simulator as well.

1

NOTE: The Towel is constantly being improved; check brooklynaerodrome.com for the latest instructions with supporting videos, parts lists, and tips on sourcing.

TIP: Practice flying directly at your head, to get the left/right control reversal sorted out. You'll learn a lot faster if you get most of your crashing done virtually.

2. CHARGE YOUR FLIGHT BATTERY

The dirty little secret of R/C cars/planes/boats is that you'll spend more money on battery chargers than most any other single item. Check brooklynaerodrome.com to see what chargers are working well and are a good value.

All modern LiPo batteries come with a charging connector that's separate from the power leads. Pictured here is a range of chargers that cost from $8 to $100. Most chargers require 12V DC power, which can come from a car battery or a dedicated AC-adapter power supply as seen at the top left.


2

2

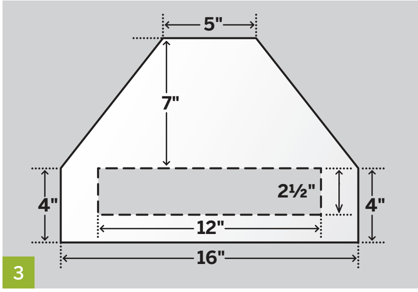
CAUTION: LiPo batteries can start fires if they're overcharged, overdischarged, or physically damaged. Never charge them unattended or leave them in a flammable environment after a crash. Charging them on ceramic tile or in a flowerpot is a good safety move.

Karen King and Breck Baldwin

3. BUILD THE DECK

Draw out the deck on your Coroplast following the deck template, and use a ruler and box cutter to cut it out. Coroplast is a difficult material to work with, and multiple light passes with a very sharp knife work best. Muscling it just annoys the Coroplast and generally results in a sliced finger. The Towel is not meant to be a Band-Aid. Keep your blood off it.

Save the scraps, you'll need some later.



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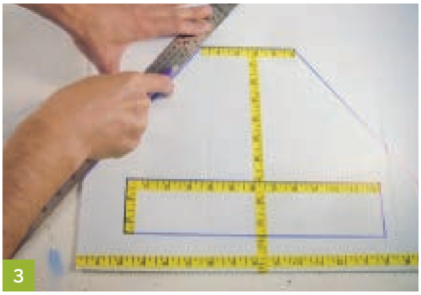

3

IMPORTANT: It's critical that the servos be well and solidly attached to the deck, and that the elevons be well connected to them. These are typical weak spots on deck builds; if they're not well attached, then on every landing or crash, the servos shift and the trim of the Towel is lost.

Out-of-trim airplanes are very hard to fly because they require constant control input for level flight.

The length of the control rods is the only thing on the deck that must be measured precisely within ±½" of precision.

4. MOUNT THE SERVOS

4a. Peel the labels off your servomotors and clean them with alcohol or another solvent if they're greasy.

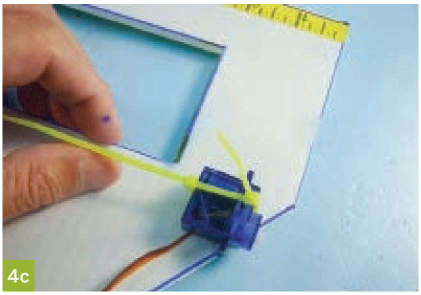
4b. Apply double-stick tape to the servos and attach them to the deck, with their wires toward the front and their shafts toward the outside edges. If the wires are short, you may need to move the servo closer to the propeller hole, or right to its edge. The prop hole is designed around the shortest servo leads we've found.

4c. The tape keeps the servo in place but it needs reinforcement from zip ties.

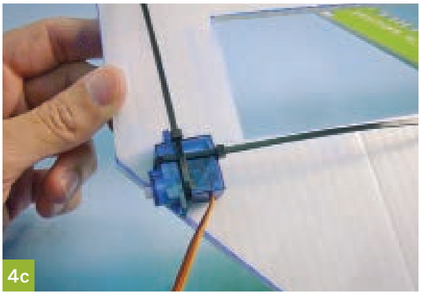
Place the holes for the zip ties very close to the servo housing so the servo can't move. If the ties are too short they can be doubled easily, as shown here.


4a


4b


4c

TIP: Crossing the zip ties yields a strong bond to the deck to withstand crashes.


4c


4c

5. MAKE THE MOTOR MOUNT

5a. Use a hacksaw to cut the angle stock to the shape shown, as wide as you need it. For this build, I needed 1".

5b. For our build we use the motor's 3 existing holes as guides to drill through the mount, then attach with zip ties. This motor required a bit of clearance in the center, so a fourth hole was needed.

5c. Next, drill holes in the motor mount for attaching it to the deck.

5d. Attach the prop saver to the motor and make sure the screws are tight without stripping the prop saver's aluminum threads. Usually the propeller shaft is cut flush with the end of the prop saver.

6. CONNECT MOTOR TO ESC

Connect the speed controller to the motor and to the battery. The male connectors go on the motor, female on the speed controller.

6a. Strip and tin all wires, 3 from the motor and 3 from the speed controller. Why 3? The speed controller runs the motor by applying current to 2 of the 3 leads at a time, in AC, believe it or not. There is a genie figuring it all out inside the speed controller. I have seen it escape in a puff of smoke on many occasions.


5a

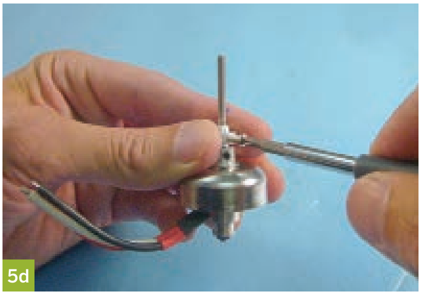
NOTES: Outrunner motors have a mounting setup that you'll have to MacGyver into connection with the airframe. Motor mounts can be made using anything from steel to 3D-printed plastic. Aluminum angle stock usually works (my favorite source is the steps from a worn-out ladder.)


5b


5b

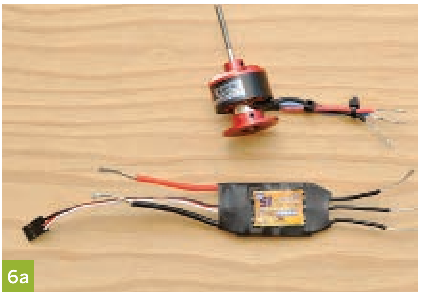

5c

The holes closest to the motor are offset. This reduces a common *stress riser* (bending/breaking point) that occurs during crashes if the holes are aligned. On the front side it doesn't matter.


5d

Our default setup, which is the "not get laughed off the model plane field" setup, requires soldering fussy little 3.5mm bullet connectors for the motor and ESC, and insulating the connections with heat-shrink tubing.

This is an opportunity for you to innovate and do something different. (We've flown planes where the connections were twisted together by hand and wrapped in electrical tape.)


6a

Gregory Hayes (6a)

6b. The trick to soldering the bullet connectors is to stick the end of the soldering iron into a small hole in the connector, fill the end with solder, and dunk the tinned lead into the bucket of molten solder for a bit until everything is all nice and melted. Let it cool. If your fingers are getting burnt, you're doing it right.

Heat-shrink it all up.

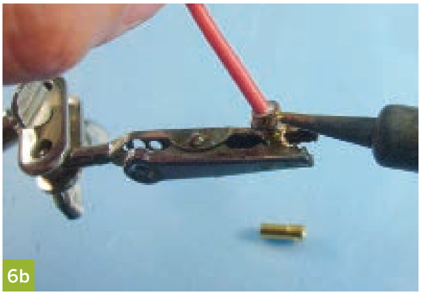
7. CONNECT BATTERY TO ESC

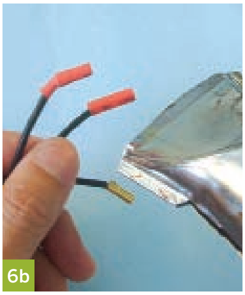
You have a broad choice of battery connections for the speed controller; we like Anderson Powerpoles. Most batteries come with some sort of connector, so you can just adopt the matching connector in that case.

8. MOUNT THE PROP

8a. Attach the prop to the prop saver, with its raised lettering facing forward. If your prop has no lettering, look closely at its blades to see the airfoil and intuit the correct orientation. Or do what I do — run it both ways and see which generates more thrust.

8b. Attach the motor to the motor mount using zip ties. Center the prop in the middle of the deck's prop hole, keeping the prop blades about ¾" away from the back edge. Punch holes in the deck through the motor mount's attachment holes and secure with zip ties.


6b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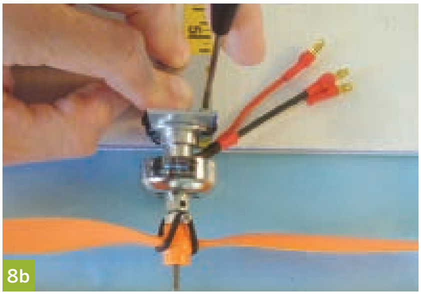
7


8a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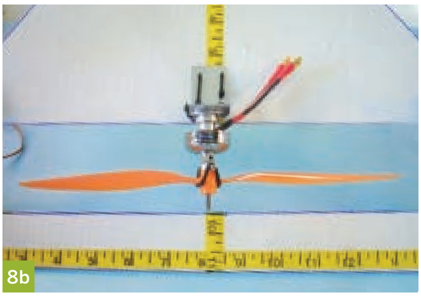

8b

NOTE: Shown in Step 7 at top is the standard Deans connection and at bottom the XT60, both of which require soldering and can be difficult to separate. In the middle is our preferred setup, with Anderson Powerpole connectors.

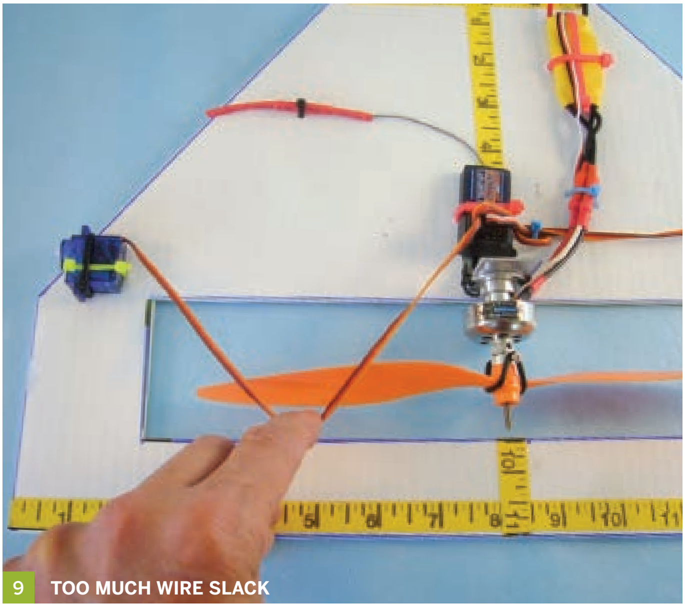
CAUTION: Be very careful to get polarity correct. Reversed battery connections will destroy both the battery and the speed controller.

9. CONNECT THE RADIO RECEIVER

9a. Follow your receiver's instructions to connect it to the right servo (channel 1), left servo (channel 2), and ESC (channel 3). If you have an onboard elevon mixer (not shown), install it according to its instructions.

Turn the transmitter on with the throttle (left stick) and its trim tab both down. Connect the battery to the ESC, and the plane should come to life: the servos move with the right stick, and the motor runs with the left stick.

9b. Secure all components to the deck with zip ties to protect against crashes, which will be a forward force, and to be sure that nothing can get pulled backward into the prop (like the wires shown here).



9 TOO MUCH WIRE SLACK

NOTES: Some radio manufacturers (such as JR) have a different mapping for the channels. Consult your manual for elevon setup.

Make sure the motor is turning clockwise, looking from back to front; if not, switch any 2 of the 3 bullet connectors to reverse its rotation.

10. ALIGN THE SERVO ARMS

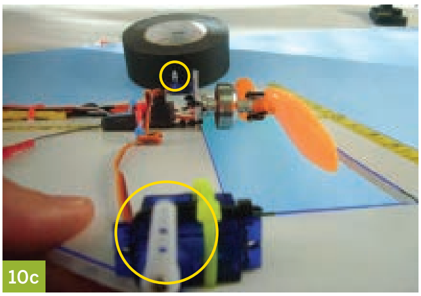
10a. Drill out the servo arm to the diameter of a coat hanger.

10b. Center the 2 trim tabs on the transmitter's right stick, for elevator (up/down) and aileron (left/right). Turn on the transmitter and power up the deck.

10c. Attach both servo arms as close to 90° as possible and add their retaining screws. If necessary, use the aileron trim tab to make their angles match exactly. Retain this trim when bending and mounting the elevon control rods.

10a

10b



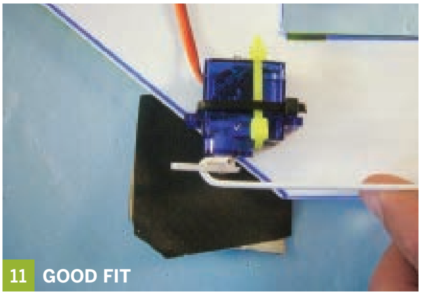
10c

TIP: If you're a beginning R/C pilot, drill the servo arm closer to the axis of rotation. This will shorten the control throws and make the Towel easier to fly. In Step 10c you can see I've drilled for both beginner and advanced settings.

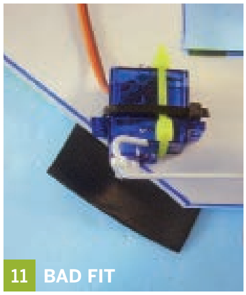
Gregory Hayes (10a)

11. BEND THE CONTROL RODS

Cut the straight bottom portion out of a coat hanger and bend a U-shaped hook on one end as shown. It's critical that the hook be just wide enough to accommodate the servo arm — if the bend is too wide, the controls may slip out of trim or bind on the servo.



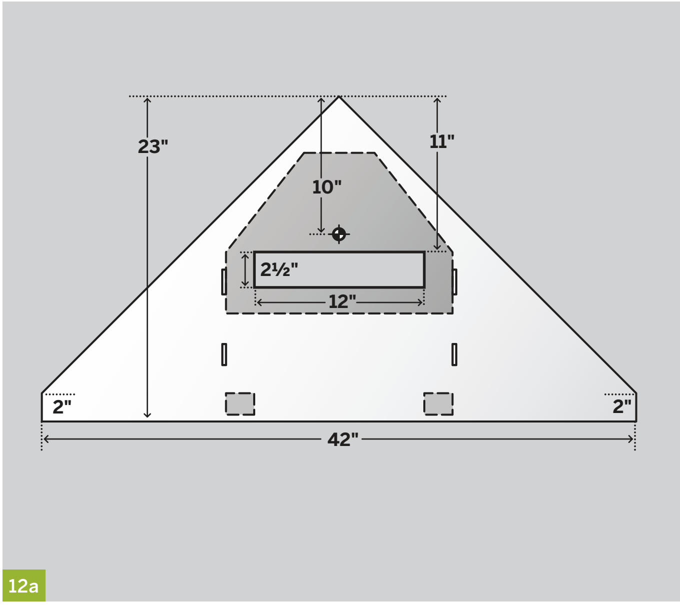
11 GOOD FIT



11 BAD FIT

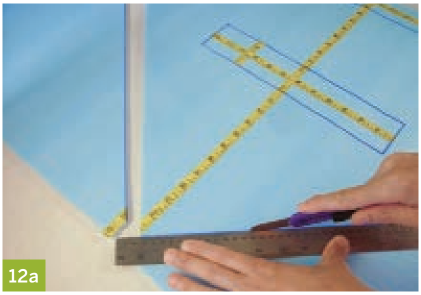
12. MAKE THE AIRFRAME

12a. Follow the template to cut the airframe out of the polystyrene foam sheet.



12a

12b. Cut the elevon free by making a single beveled cut of around 30° as shown here. The degree of bevel isn't crucial, but try to keep it constant for the length of the elevon.



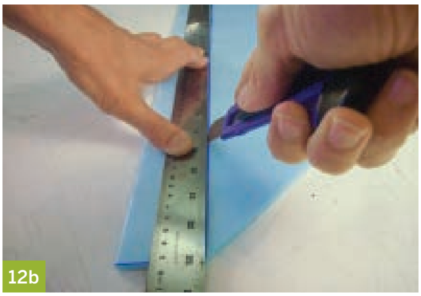
12a

TIP: Use a sharp blade, because ragged edges will compromise all your hard work for tight servos.

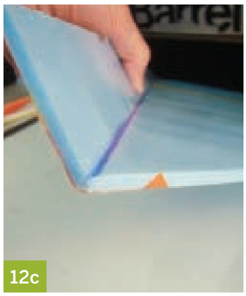
12c. Flip the airframe over facedown while leaving the elevon in place face up. Fit them together and accurately tape in a few places the joint that's formed by the beveled cut. Then apply a strip of packing tape the length of the elevon. Don't sweat the wrinkles. Only this side needs to be taped.

Make a ¼" slot in the elevon mid-span, to create 2 elevons that move independently.

Flip the airframe face up again so the hinge is on the work surface. Notice how the bevel works to allow the elevon's upward motion.



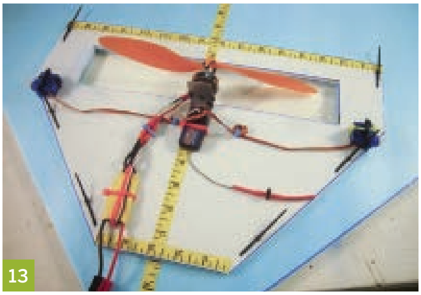
12b



12c

13. ATTACH THE DECK

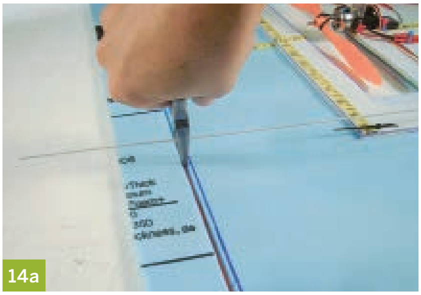
Align the prop holes in the deck and the airframe, and attach them with 6 zip ties that pass through both pieces.


13

CAUTION: Keep the airplane powered up until the elevon control horns are mounted, to ensure that trim is maintained. Be careful to not hit the throttle by mistake.

14. MOUNT THE RODS

14a. Attach the control rods to the servos, with the rods running outside the servo arms. Use the pliers to make a 90° bend in each rod, just aft of the hinge, bending toward the center of the airframe.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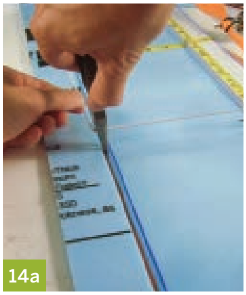
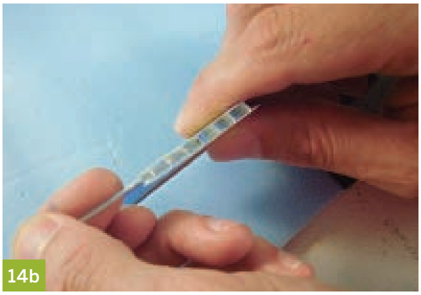

14a


14a

NOTE: It's important to align the bend points for both rods to ensure that the elevons move the same distance. If one is too long, you can use the trimming technique discussed in Step 16 to match them up — otherwise get another hanger and try again.

14b. Take 1½" of the prop cutout material from the deck and cut it in half. Force the end of the control rods through the flutes of the Coroplast, crosswise, to make 2 control horns. (You can't use a flute as the hinge point because it's too big and sloppy.) Lay the airframe flat and attach each control horn to its elevon with 2 zip ties.

Start making airplane sounds; you're almost done.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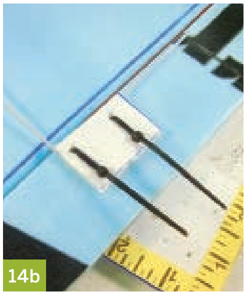
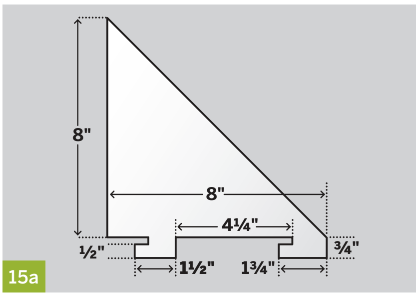

14b

15. MAKE THE STABILIZERS

15a. Cut out the 2 stabilizers following the template, after first reinforcing the lugs with packing tape on both sides. Cut with extra care around the lugs.



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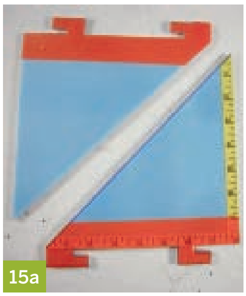
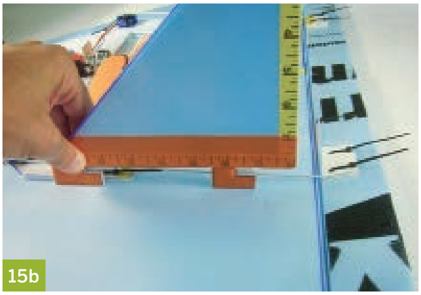
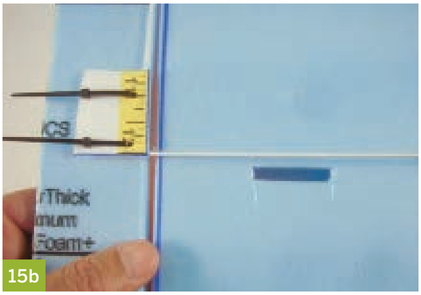

15a

15b. Line up the stabilizers right next to the control rods about ¾" forward of the hinge. Carefully cut the slots for the stabilizer lugs.



15b

NOTES: Slightly too tight is better than too loose, otherwise the stabilizers will wobble. (This can be fixed with tape easily enough.)



15b

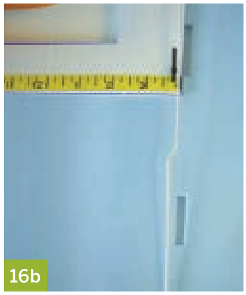
If built perfectly, the elevons should lie flat on the table. Generally that's not the case, so don't worry.

16. ADJUST THE TRIM

16a. Put the airframe on a flat surface, power up the plane and transmitter, and recheck that the servo arms are aligned, with any aileron trim tab adjustments. The goal is ¼" of "up trim" in both elevons. This is the thickness of the blue foam. If you have more than ¼" up trim already built in, then the control rod will have to be remade.

16b. If there's less than ¼" up trim, then bend a "dogleg" in the control rod with the needlenose pliers while gripping it firmly, to effectively shorten the control rod.

16a



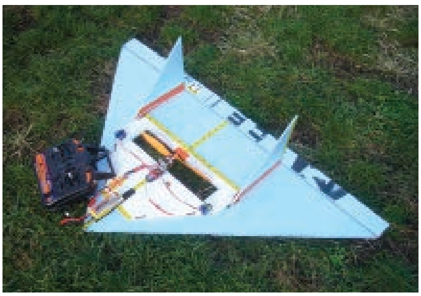
16b

17. MOUNT THE BATTERY

17a. Stick the hook side of the velcro tape to the Towel, half on the deck and half on the airframe. Apply the loop side of the velcro to the battery pack. Make sure the battery is charged, then attach it to the Towel.

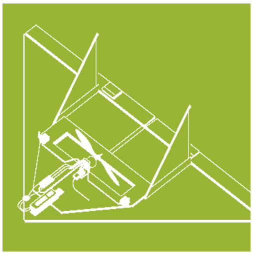
17b. Test the center of gravity (CG) by balancing the plane on your fingers. The Towel works really well with its CG at 10" from the nose. Adjust the CG by moving the battery pack's position. That's it!

17b



TEST BUILDER: Daniel Spangler, MAKE Labs

USE IT.



HAVE TOWEL, WILL TRAVEL

Know Your Controls

Throttle: The transmitter's left stick is the throttle: push it forward to go faster, pull it backward to go slower.

The transmitter's right stick operates the elevons as follows:

Pitch: Elevator signal determines the plane's up/down attitude, or pitch. Pull the stick back to angle the nose up (both elevons go up), and push it forward to nose down (both elevons go down). It's the reverse of a game controller.

Roll: Aileron signal determines the plane's roll to the left or right. (It's not really left and right turning — that's yaw, and the Towel doesn't use the rudder signal.) Push the stick left to roll the plane left (raise the left elevon and lower the right elevon). Push it right to roll right (raise the right and lower the left elevon).

Elevon mixing: If your radio supports elevon mixing, follow the manual to achieve it. An onboard elevon mixer, aka V-tail mixer, should also provide instructions; it's shown here (inset) connected but not yet zip-tied in place.

Control throws: The beginner-level control throws are ±¾" in both pitch and roll. If you know how to fly, then double that. Adjust the throws by either using dual rates on your transmitter or moving the servo horn holes inward (reduce throw) or outward (increase throw).

Karen King and Breck Baldwin

Flight School

A well-built Towel takes damage like a B-17 bomber takes flak — if the motor's still turning, then it's flying. A few tips for successful flight:

CG and trim: The plane built for this article flew perfectly with the trim and center of gravity shown here. Get this right – it's critical.

Launching: I launch the plane with my left hand, while my right thumb keeps constant contact with the right stick. I run up the throttle with my chin, up to about two-thirds throttle, and release smoothly into the air. I do not throw the Towel, nor do I drop it. It's an easy, straight toss. Since my thumb is on the elevon controls, it's easy to correct wind disturbances and "off" launches.

Flight training: If you're a newbie, we recommend the Splinter Method of flight training. This is best done over deep grass in a big field with nothing to hit.

a. Have someone else launch the plane with 50% power. The pilot's job is to keep the wings and nose level and cut throttle before the plane settles into the ground, which it should do in a few feet at 50%.

b. Once that's working well, increase power to 75%. Fly the plane straight for 50 feet and land it by cutting throttle. Repeat until this is smooth.

c. The pilot then launches their own plane at 75% power for a 50-foot flight. No turns!

d. Once comfortable with launching and landing, the pilot will attempt to turn 180° and then land. Any sign of trouble and the immediate reaction is to cut throttle and keep the nose level. You should note that when the Towel flies at you, the left and right controls are reversed! Flight simulator time will really help with this.

e. The pilot will then attempt a 360° turn and landing.

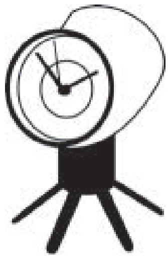
f. Now the pilot can attempt figure-eights and further skill building.

Flight time: Standard battery packs in the range suggested will last 6–7 minutes, and take about 25 minutes to charge. Not all speed controllers have reliable automatic cutoffs for low voltage, so be mindful.

With that said — fly your Towel, send us a picture at brooklynaerodrome.com, make something different, improve upon the design, and share your build at makeprojects.com.

Videos of Towels in flight, at night, with onboard cameras, and more: youtube.com/user/brooklynaerodrome

Gregory Hayes



PIPE DREAMS

Build sturdy furnishings with PVC pipe and a few tricks.

By Larry Cotton and Phil Bowie

Humble PVC drain pipe is cheap, widely available, easy to work with, and almost endlessly useful for making everything from patio furniture to elegant sculptures.

Here are four family-friendly projects that use 3"- or 4"-ID (inside diameter) PVC pipe. In a weekend you can easily make all four: a kids' table with a dry-erase top and matching stool, a two-faced clock to help you remember friends in another time zone, a hanging planter, and an accent lamp that seems to float on light.

You can make them with handheld tools, but bench tools such as a band saw or table saw with a fine-toothed blade work best for making square and accurate cuts. PVC also bends easily when heated in boiling water, which opens up all kinds of new shapes and design possibilities.

If cutting pipe from a 10' length, ask a friend to help support it. Use a face mask and ear protection for cutting and sanding.

Fill any dings with automotive body filler and/or glaze. Then sand the pipe parts with 180-grit sandpaper, prime, and paint. If you want to skip the primer, there are new spray paints that adhere directly to plastic.

⚠ WARNING: PVC pipe tends to roll while cutting on a table saw, so hold it firmly and cut slowly. Gripper gloves help. For cutting off sections on a table saw, set the blade just slightly higher than the pipe wall thickness. Don't use a ruler or tape to set blade height; instead, make trial cuts in a scrap of wood and measure the cuts. Always wear eye protection when using power saws.

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

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

Gregory Hayes

SET UP: p.99 **MAKE IT: p.100**




24
04
08
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20


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Kate

CUT IT, DRILL IT, BEND IT, PAINT IT

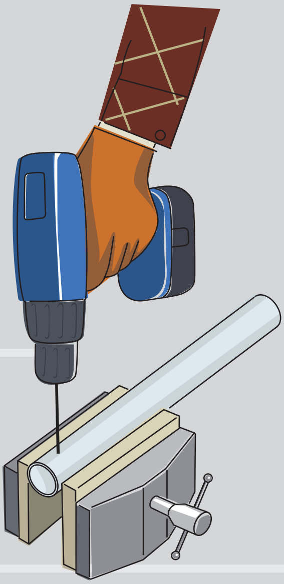
Polyvinyl chloride (PVC) plastic pipe is strong, works like wood, and accepts various fillers and finishes. It's also thermoplastic, so it can do something wood can't — bend into new shapes with the application of heat. Here are techniques for making your own furnishings from PVC.

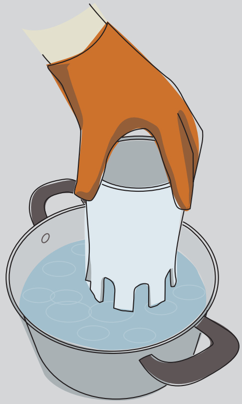
CUTTING

PVC pipe is easily cut with small-toothed handsaws. A hacksaw is slow but relatively accurate.

For straighter cuts, you can use a table saw, band saw, or miter saw (aka chop saw). To avoid chip-outs and minimize the danger of kickback, use a sharp, fine-toothed blade and move the work piece into the blade very slowly. On a table saw, use a rip fence and miter gauge to keep cuts square. On a band saw, set the upper guard properly.

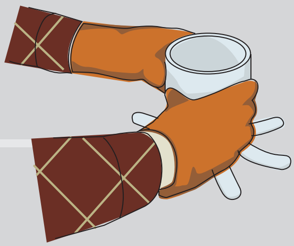
To keep pipe from rolling while you're cutting, clamp it to a workbench or in a vise (with a handsaw), or to the fence (with a miter saw), and wear gripper gloves with any power saw.





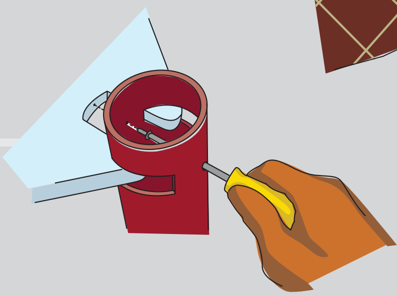
DRILLING

When drilling PVC, the bit will grab the plastic firmly — so commit to your drilling motion and follow through. Stopping halfway can leave chunky waste material in the hole, or cause chip-outs. Grip the pipe in a vise or clamp it in a V-groove in a board to prevent rolling.



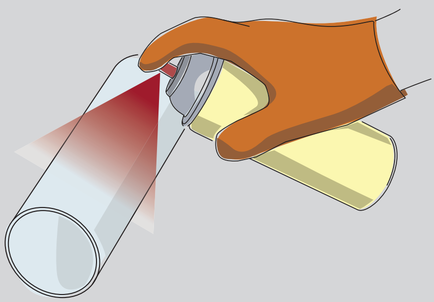
BENDING

PVC is thermoplastic; heat it up and bend it into any shape you like. In this project you'll use boiling water; we also like the PVC Bendit heating tool (see box, opposite).



FASTENING

Wood screws or self-tapping sheet metal screws provide a strong hold in PVC pipe. The kids' table in this project also makes use of interlocking slots for a stronger connection.



FINISHING

Flaws in PVC are easily filled using automotive epoxy putties and glazing and filling compounds.

PVC sands like wood and accepts automotive primer before painting. A new generation of spray paints will bond directly to PVC without primer.

PVC is also easily stained — see "1-2-3: Stain PVC Any Color" on page 117. Acetone will clean off most factory markings.

Tim Lillis

SET UP.


A


B

COOL NEW TOOL
The **PVC Bendit** wasn't used in these projects but it does a nice job creating PVC furniture and structures. This new gadget gently heats plastic pipe up to 4" in diameter, making it pliable so you can bend it to any shape. MAKE Labs tested it and it works great; see the review in last issue's Toolbox section.


C

D

MATERIALS

TABLE AND STOOL

A. PVC pipe:
- » **White, 4" ID × ¼" wall, 10½" length** for the stool. Buy a 10' length, Lowe's part #23838, and use it for the other projects too. We used cheap, foam-core Schedule 40 sewer-and-drain PVC but other types of PVC will work.
- » **White, 3" ID × ¼" wall, 10' length** Lowe's #23834, for table legs

B. Screws:
- » **Sheet metal screws, #10×1" Phillips head (4)**
- » **Wood screws, #8×1" flathead (12)**

- » **Plywood, ¾" thick: 2'×2' (1); 12" diameter rounds (2); 4" diameter rounds (2)**
- » **Dry-erase board, about 48"×32"** Lowe's #61082, for table and stool tops
- » **Contact cement, Weldwood ("The Original"), 14oz**
- » **Wood dowel, ¼" diameter, 6" length**
- » **Scrap wood** for making a miter gauge extension

CLOCK

C. Clock movements, 2⅛"×2⅛"×⅝", with hands (2) for 12- or 24-hour time. 24-hour movements at klockit.com.

- » **PVC fitting for 4" ID pipe, white, 45° elbow with ⅛" wall** Lowe's #24124. This has a ⅛" wall at the openings.
- » **Plywood, ¾", 4½" diameter (2)**
- » **Hardboard, ⅛", 4½" diameter (2)** or dry-erase board
- » **Photo paper, white, heavyweight**
- » **Sheet metal screws, #6×½" (2)**
- » **Batteries, AA (2)**

LAMP
- » **PVC pipe, white, 4" ID × ¼" wall, 14" length**
- » **Switch, SPST, with round bushing and nut** Lowe's #71393
- » **Plywood, ½", 4" diameter round**
- » **Threaded nipple, 1"×⅜" diameter** Lowe's #46816
- » **Socket, for standard lamp bulb** Lowe's #70826
- » **Wire nut**
- » **Lamp cord, 120V rated**
- » **Lamp bulb, 40W maximum, frosted incandescent or CFL**
- » **Acrylic rod, ¼" diameter, 10" length** for the feet. You can also use a tilt wand for Venetian blinds.
- » **Cyanoacrylate glue** aka super glue or crazy glue

PLANTER
- » **PVC pipe, white, 4" ID × ¼" wall, 8" length**
- » **Nylon monofilament fishing line**
- » **Clay or plastic pot, 4" diameter**

For all projects:

D. Paint and primer:
- » **Spray paint** various colors. If you're using primer, you can use most any paint. To skip the primer, use Krylon Fusion or Rust-Oleum Paint for Plastic; they're formulated to bond directly to plastic.
- » **Spray automotive primer (optional)** Rust-Oleum or equivalent

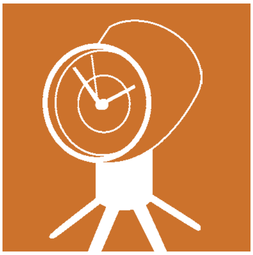
- » **Automotive body filler putty and/or automotive glaze** such as Bondo filler or DuPont 315 glaze
- » **Sandpaper, 180 grit**
- » **Masking tape**
- » **Hot glue and/or epoxy**

TOOLS

- » **Saw** for cutting plastic pipe. Handheld saws will work, but we recommend a band saw or a table saw with a miter gauge and a fine-toothed blade.
- » **Drill and drill bits: 1⁄16", ⅛", ¼", ⅜", ¾" spade, countersink**
- » **Combination square (optional)**
- » **Marking compass or ¾" dowel.**
- » **Jigsaw with fine-toothed blade** for cutting plywood
- » **File or high-speed rotary tool (optional)** such as a Dremel
- » **Screwdriver or long driver bit, Phillips head**
- » **Measuring tape**
- » **Hot glue gun (optional)**

Gregory Hayes

MAKE IT.



BUILD YOUR PVC FURNITURE

Time: A Few Hours
Complexity: Easy

KIDS' TABLE AND STOOL

This small table fits young kids perfectly — and they can scribble to their hearts' content on the dry-erase tabletop.

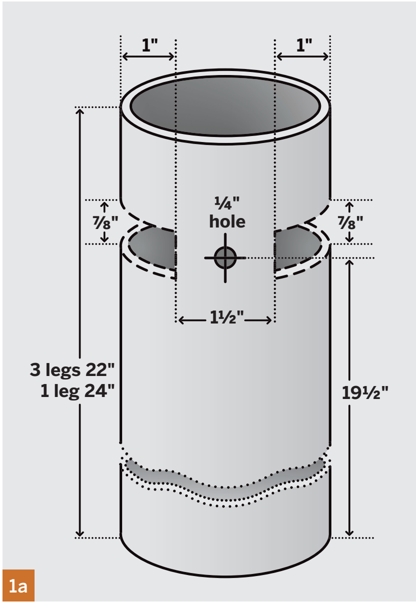
1. MAKE THE TABLE LEGS

1a. Cut them from a 10' length of 3"-ID pipe. It's best to use a table saw with a rip fence and a miter gauge to keep the slots and pipe ends square and parallel.

1b. Wrap a measuring tape around one end of a leg and put marks at the starting point and at exactly half the distance around the leg. Drill — from the outside, not straight across — ⅛" holes through both sides of the legs. Then drill straight across to enlarge both holes to ¼".

1c. Using this technique and the first leg as a guide, drill the holes in the other 3 legs. All holes are 19½" from the bottom ends.

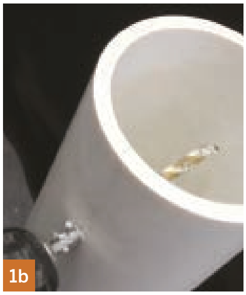
1d. Insert a 6"-long, ¼"-diameter wood dowel in the first leg, held by tape inside.



1a

NOTE: One leg is longer than the others (for storing markers and an eraser).


1b


1b


1c


1d

Larry Cotton and Phil Bowie

1e. Slot one leg to mate with the tabletop. The dowel in the pipe will ride on its top surface so the finished leg slots will be perfectly aligned.

Set the table-saw blade depth to exactly 1". Using the miter-gauge extension, cut the slots in the leg. The slot dimensions and positions are critical to ensure that your table is sturdy and all 4 legs are perpendicular to the top.

1f. Remove the dowel. (The holes will be used to attach the legs to the table.)

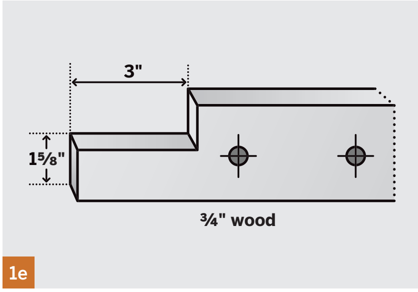
1g. Repeat Steps 1d–1f for the other legs. When slotting the longer one, the rip fence (parallel to the blade) must be moved to accommodate that leg's extra length.

Paint the legs a bright color. Hanging the legs horizontally while painting helps.

2. MAKE THE TABLETOP

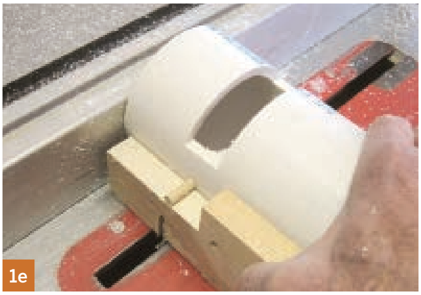
2a. For the tabletop core, we used smooth ¾" plywood, 2'×2'. For more durability, use exterior plywood. The top surface is ⅛" dry-erase board.

2b. Cut a slightly oversized piece of dry-erase board and laminate it to the plywood using Weldwood ("The Original") contact cement. Follow the container directions exactly. After pressing the 2 pieces tightly together, trim all sides and sand the edges smooth. Avoid scratching the dry-erase surface.



1e

NOTES: If you use a table saw, first make a miter-gauge extension from ¾"-thick scrap wood as shown in this diagram.


1e

While cutting, make multiple small passes and be sure the side of the dowel always stays in contact with the miter-gauge extension.


1e


1g

2c. Lay out the 4 identical corners. A combination square is helpful. Draw the radius at the back of each slot with a thin ring of 3"-ID pipe, then use a compass or the end of a ¾" dowel to mark the 8 radii at the slot ends.

2d. To facilitate cutting, drill ⅜"-diameter holes in the corners of each slot, then cut with a handheld jigsaw with a fine-toothed blade. Sand, file, or Dremel the slots until the legs fit snugly into them. This will ensure the table doesn't wobble.

2e. Fill any imperfections in the legs and the top's edges with Bondo and/or glazing putty. Mask the top and paint its edges white. Paint its bottom for more durability.

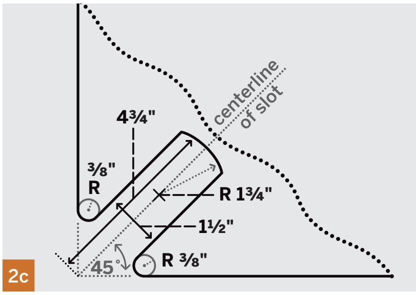
3. ASSEMBLE THE TABLE

3a. Use four #10×1" Phillips-head sheet metal screws to screw the legs into the tabletop.

3b. To cap the legs, cut 3" disks from the dry-erase board and drop them into the tops of the legs.

4. MAKE THE STOOL

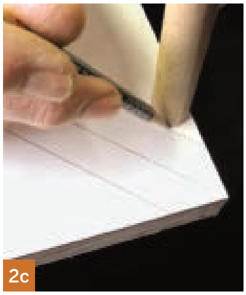
4a. For the column, cut a 10½" length of 4"-ID pipe and drill 6 clearance holes in it as shown in the diagram. Countersink them so the #8 screws will sit flush.



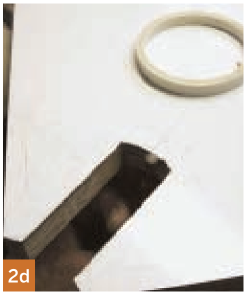
2c


2c

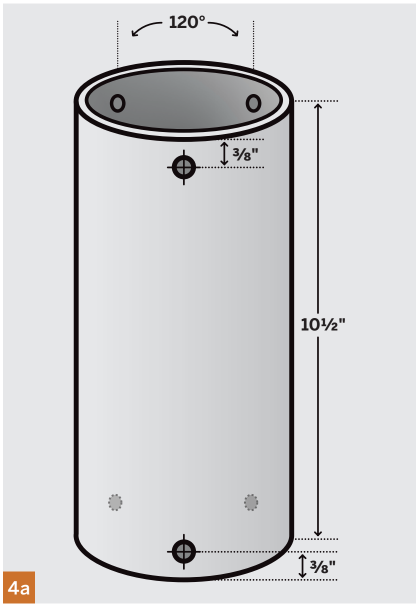

2c


2c

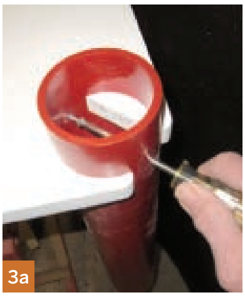

2d


2d


3a



4a


3a

4b. Cut 2 disks of ¾" plywood to fit snugly into the 4" pipe. Cut 2 more ¾" plywood disks 12" in diameter for the stool's top and bottom.

4c. Attach the small disks to the centers of the large disks using three #8×1" screws each.

Laminate an oversized disk of dry-erase board to one of the disks for the top.

4d. Trim, sand, and finish the top and bottom to match the tabletop.

Assemble the stool with six #8×1" flathead wood screws.


4b

TIP: For speed and accuracy, cut plywood disks on a band saw and pivot the plywood on a brad with its head snipped off.


4c


4d


4d

TWO-FACED CLOCK

If you and a friend or relative live in different time zones, keep track with this two-faced clock. The housing is a 45° PVC elbow for 4" ID pipe. Be sure to get the lighter one with ⅛" walls. The clock movements are the ubiquitous AA-battery plastic boxes. Remove them from old clocks or buy them online.

1. MAKE SPACERS

Cut two ¾" plywood spacers to slip-fit into the elbow ends and core them out with a jigsaw or band saw to clear the clock movements.

2. MAKE FACE BACKING PLATES

Cut 2 disks from dry-erase board to slip-fit on top of the

TWO-FACED CLOCK


2


2

spacers. Sand the edges.

To drill the exact center of a disk, you can draw 2 chords, bisect them with perpendicular lines, and drill where the lines intersect.

3. MAKE CLOCK FACES

Use your imagination to design 2 clock faces, then print them on thick paper. Add names to the faces to match whichever time zone your friend or relative lives in.

4. ASSEMBLE THE CLOCKS

Glue the faces, backing plates, and spacers together. Add the movements, mounting nuts, and AA batteries.

Clip the hands to fit (if necessary), push them onto their respective spindles, and set their times.

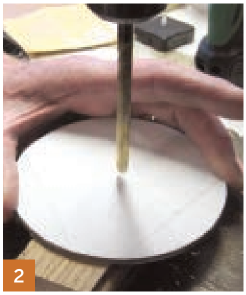
5. INSTALL THE CLOCKS

Orient one face carefully (the seam on the elbow can help), then insert the assembly into the elbow. Affix it with one #6×½" sheet metal screw. Repeat for the other opening.

6. GO FURTHER

We left our elbow unmodified (including bar code label), but here are a few suggestions for other clocks and bases using PVC pipe.

2



2

How about a NASA photo of the world? Or make 12-hour and 24-hour faces. Or a galaxy, with hands painted to resemble meteors? Here are a few that we designed; you can download them at makeprojects.com/v/30.

3

6

FLOATING ACCENT LAMP

This lamp adds a romantic glow to any room. Designed to provide good airflow around the bulb, it seems to float magically on a soft ring of light around its base.

1. MAKE THE HOUSING

Cut and drill the bulb support from ½" plywood, following the diagram.

One 45°-angled cut in the 4" PVC easily allows you to make 2 lamp housings if you wish. Drill the hole in back to fit your switch, 2" from the pipe bottom. Thoroughly sand the angle and the bottom surfaces.

2. ASSEMBLE THE LAMP PARTS

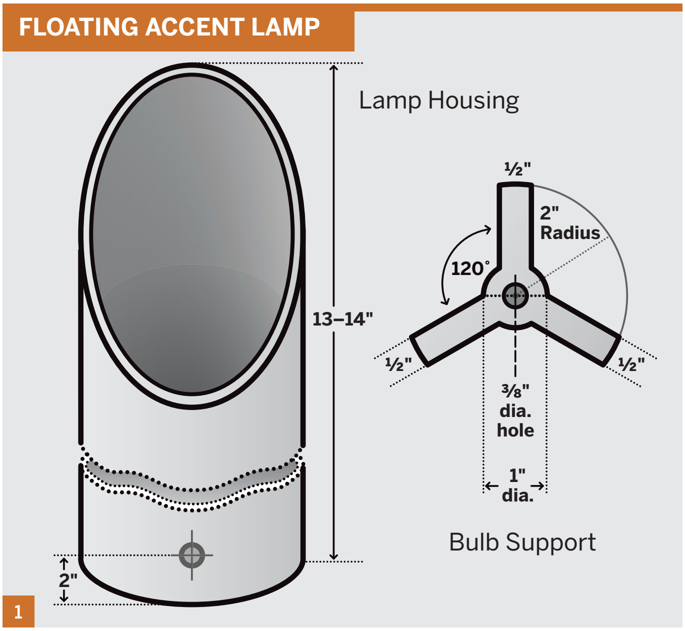
Thread the nipple through the bulb support, add the socket, and wire up the switch. Ensure that all electrical connections are tight and insulated.

Screw in a 40W (maximum) frosted or CFL bulb and test.

3. PAINT

Mask the inside of the PVC housing, then sand and paint the outside a bright color.

Reverse the masking and paint the elliptical rim, the bottom rim, and the inside white.



1


1


1


2

4. INSTALL THE LAMP ASSEMBLY

Mount the switch, and then hot-glue the bulb support assembly into the lamp about 1" from the bottom.


4

5. GLUE ON THE FEET

Super-glue at least six ¼"-diameter, 1½"-long clear feet inside the bottom rim. We used acrylic rod. Sand the mating surfaces thoroughly before gluing. Notch a scrap of wood and use it as a jig to ensure that the feet protrude the same amount.


5

IMPORTANT: Make sure the bulb is centered in the pipe.


5

PLANT HOLDER

This versatile and attractive plant holder holds a standard 4" flowerpot in a variety of ways. You can set the pot in either end and use the holder upside down or right side up. In either position, you can hang it, or just place it on any surface.

1. CUT AND DRILL THE PIPE

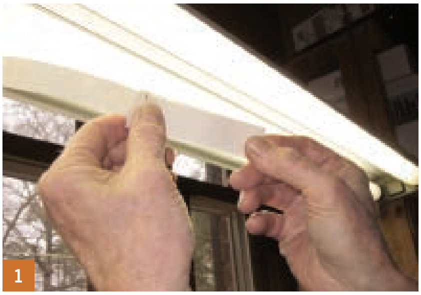
Cut an 8" length of 4"-ID pipe and mark 8 evenly spaced spots 3" from one end to drill holes.

To space the holes, wrap a strip of paper around the pipe and mark a line across both ends. Hold the strip in front of a light to align the marks and fold the strip in half. Then fold in half twice more. Mark the pipe at the fold lines.

Using a spade bit, drill eight ¾" holes.

PLANT HOLDER


1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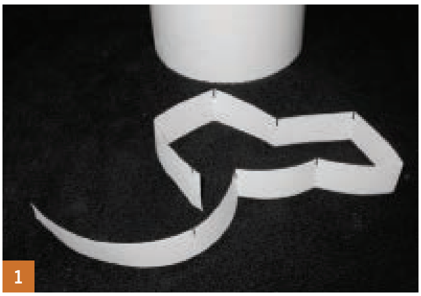
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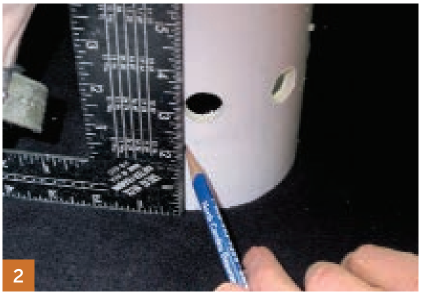
2. MARK AND CUT SLOTS

Draw lines from each hole to the pipe end. Then cut the slots with a handheld jigsaw.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2

3. BEND THE LEGS

Boil 3½" of water in a large cooking pot. Using gloves, immerse the slotted pipe end until the legs become very pliable. Bend the legs out away from the body a bit.

Remove the pipe from the water, then while keeping the pipe perpendicular, push the legs down onto a cookie sheet. The legs will splay out. Allow to cool for a minute. Repeat if you need to correct any faults.


3


3

4. FINISH THE LEGS

Round the leg ends with a disc sander, then file and sand the legs smooth. To hang your plant holder, drill a 1/16" hole in the center of each leg end.

5. FIT A FLOWER-POT AND PAINT

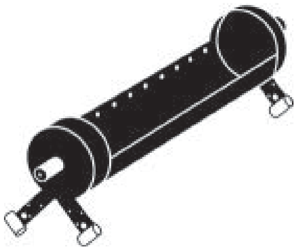
Some pots fit the holder better if you chamfer the inside top edge. Use the pot itself as a backing surface for coarse sandpaper.

Spray it a bright color or leave it white. Attach mono-filament line to each leg for hanging.


5


5

TEST BUILDER: Max Eliaser, MAKE Labs



YAKITORI GRILL

Get cookin' with this Japanese-style skewer grill.

By Bob Knetzger

One of the most memorable and delicious aspects of travel is sampling the local foods. A trip to Japan gave me a chance to enjoy favorites like *takoyaki* (octopus fritters), *okonomiyaki* (cabbage frittatas), and other Asian eats in their native setting. A new (to me) treat was *yakitori*, a simple bar food snack of grilled chicken.

In the Tokyo neighborhood of Shinjuku, I saw (and smelled) enticing restaurants featuring sizzling street-side grills. Unlike big American grills that cook anything from burgers to ribs to steaks, these specially sized grills were designed to do one thing and one thing only: skewers. Short skewers loaded with chicken, asparagus, meatballs, and other simple ingredients spanned the narrow troughs of red-hot coals. The suspended foods cooked quickly and without burning or sticking to a grate or grill surface. And the offerings included nearly all the parts of the chicken, from succulent breast (*torinku*) to crunchy cartilage (*nankotsu*) and delicate, crispy chicken skin (*torikawa*). Yum!

Back home, I wanted a way to cook yakitori myself, so I came up with this easy-to-make grill design and some specially designed roll-proof, double-crook skewers. Use them to try delicious yakitori recipes.

Bob Knetzger (neotoybob@yahoo.com) is an inventor/designer with 30 years experience making fun stuff. He's created educational software, video and board games, and all kinds of toys from high tech electronics down to "free inside!" cereal box premiums.

Gregory Hayes

SET UP: p.111 | MAKE IT: p.112 | USE IT: p.116


Maker Faire

LAND OF THE RISING SIZZLE

The materials used to make the grill are found at any home building supply store. The basic design is simple: a single piece of sheet metal is rolled into a half cylinder to serve as the

(A) trough for the coals.

(B) Aluminum cake pans help form the trough and

(C) cork handles keep it cool. The grill stands on

(D) metal L-strap legs with insulated cork feet. Pop rivets hold it all together.

SMART SKEWER

The "double crook" shape holds the skewer in two 180° positions — it won't roll — for best grilling.

Jessica Fortner

SET UP.


A

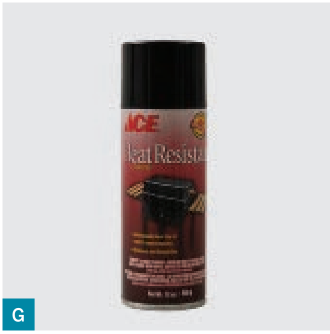

B


C


D


E


F



G


H

WARNING: Don't use galvanized steel for the main body of the grill. The zinc coating gives off dangerous fumes when heated — not good for a food-making project!

MATERIALS

A. Cake pans, aluminum, 6" diameter (2) also sold as deep-dish pizza pans. We found them at webrestaurantstore.com
B. L-straps, steel, 6"×2" deep (2)
C. Aluminum sheet, 12"×24"×0.019"
D. Pop rivets and washers, stainless steel, 1/8", assorted (14)
E. Corks (16) Use real cork corks from wine bottles, not the new synthetic ones.
F. Machine screws, #4-40 × 2", flat head, with matching nuts and washers (2)
G. Spray paint, high temperature used for grills or wood stoves

For skewers:
H. Stainless steel rod, 1/8" diameter, about 12' such as McMaster-Carr #89535K22, mcmaster.com

TOOLS

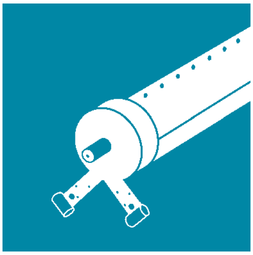
» **Sandpaper, 100-grit**
» **Measuring tape**
» **Marker**
» **Straightedge**
» **Hammer**
» **Center punch**
» **Pop rivet tool**
» **Drill with 5/32" and 3/32" bits**
» **Scrap wood block** at least as thick as depth of cake pans
» **Safety gloves**

For skewers:
» **Vise-grips** ideally needlenose **Hacksaw, heavy cutting pliers, or high-speed rotary tool with cut-off wheel**
» **Bench grinder (optional)** for deburring and sharpening

For cooking:
» **Charcoal**

Gregory Hayes

MAKE IT.



BUILD YOUR YAKITORI GRILL

Time: 3–4 Hours
Complexity: Moderate

1. PREPARE THE SHEET METAL

1a. Sand down any sharp edges or burrs on the aluminum sheet with 100-grit sandpaper. For extra safety, wear gloves when handling the sheet metal.


1b

1b. Measure and mark a series of 5/32" holes that will serve as holders for the skewers. Make a line ½" below the 24" edge of the aluminum sheet. Starting 3" from the end, measure and mark 10 holes with 2" between their centers.

Use the center punch and hammer to make dimples, to keep the drill bit from wandering when you drill. Then drill all 10 holes.


1b

1c. Drill 5 holes along each short end of the sheet. These holes will be for attaching the pop rivets to the rims of the cake pans. Draw a line 1" in from the edge, then measure, mark, and punch the position of 1 hole at dead center, 6" in from each side. Then do the same for 2 holes 1" from each side, and 2 holes 3½" from each side. Drill them with the 3/32" bit.


1c

Bob Knetzger

2. PREPARE THE PANS

2a. Find the center of the pan, mark, and punch. Draw a line from the center to the rim of the pan. Use this line to center the L-strap legs as shown in 2c, and carefully mark the location of the L-strap holes on the pan.

2b. Use a block of wood as a support inside the pan. Center-punch and drill all 3 holes. Repeat with the other pan so they're identical.

2c. Use a pop rivet, with a washer on the inside, to fasten the L-strap leg to the outside of the pan. Repeat with the other pan and leg.

3. TEST-FIT THE PARTS

3a. Gently roll the aluminum sheet to the 6"-diameter curve. Don't try to bend it all in one pass, just slightly curve it against a tabletop, and slowly and gradually roll the sheet to bend the curve as you go. Check your progress using a pan.

3b. Now "dry-fit" the parts. Place the curved trough inside the end caps on a flat, even surface, making sure all 4 feet are level and touching at the same time.

Hold the pans tight against the curved edge of the sheet, and mark the location of the holes in the sheet on the inside of the caps.


2a


2a


2c


3a


3b

NOTE: I adjusted the position of the side with the holes so that it was ½" lower than the other side — this will help level the double-crook skewers if you want to make and use them with the grill. If you want to use ordinary bamboo skewers, just center the trough. In any event, it's not critical.

If you'll grill in a windy area, you could make the trough a little deeper, or even design a lid for it.

3c. Now use the holes already drilled in the trough to mark the locations of the matching holes in the pans. Use a marker to carefully mark the position of each hole on the inside rim of each pan.

Strike the marks gently with a center punch, then flip over and punch the same marks from the other side to convert them to dimples on the *outside* of the rim. That will make it easier to drill from the outside. Support with a wood block inside and drill the matching 5⁄32" rim holes.

4. ASSEMBLE AND PAINT

4a. Line up the holes on the trough and the pans, and connect them with pop rivets. Use washers to back up on the inside and ensure snug riveting.

4b. Mask off the inside surfaces with paper and masking tape. Then paint with 2 coats of high-temp stove paint. Let dry overnight.

5. MAKE THE FEET AND HANDLES

5a. For the feet, use a hobby knife to make a slit along the length but not all the way to the end of a cork, as shown. Carve out a little more cork material to make a slot that will fit snugly on the edge of the leg. Make 3 more cork pads, one for each foot.


4a


4a


4b


5a

NOTE: If the corks are loose, use some wire to poke through the cork and a hole in the leg. Twist the wire to secure.

5b. Drill a ⅛" hole through the axis of 2 corks. Use a small flathead bolt to fasten the cork to the center hole on the end cap with a washer and nut on the inside. Tighten the nut very snugly to pull the bolt head flush with the cork — you don't want to touch the metal bolt when you pick up the grill by these insulated cork handles.

6. MAKE THE SKEWERS

6a. To make the double-crook skewers, cut the steel rods to about 14" lengths, then use vise-grips to make the bends as shown. Dimensions aren't critical, but make the bends into a zigzag shape.

6b. Drill a 3⁄32" hole through the center axis of a wine cork and drill a second, shallow, 3⁄32" hole between the center and the edge of the cork.

Thread the cork on the short end of the skewer. Use the needlenose pliers to make a very tight U-shaped bend at the end of the wire. Then slide the bent end into the second hole on the cork. This gives the skewer an insulated handle that won't spin. Make as many skewers as you like.

If you don't want to make these special skewers, you can use any kind of skewers. Look for flat cross-section bamboo skewers if you can find them — they'll rest on the grill edge without rolling until you flip them.

Gregory Hayes (6a, 6b)

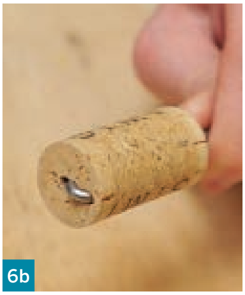

5b

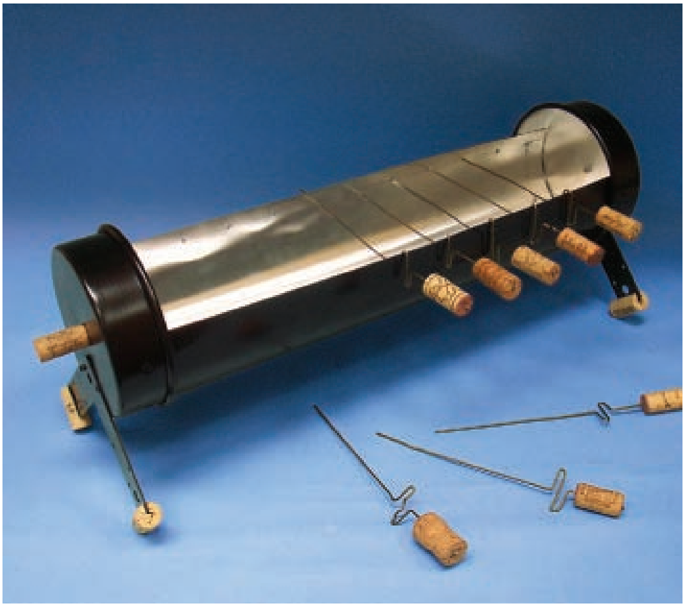

5b


6a

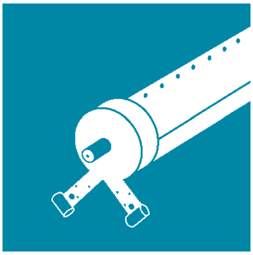
TEST BUILDER: Eric Chu, MAKE Labs


6b


6b



USE IT.



LET'S GET COOKIN'

Put the grill on a fireproof surface away from any flammable vegetation or structures. Use crumpled paper and make a mound of charcoal in the center of the grill. For best flavor use binchotan (special Japanese high-carbon content, "white" charcoal) or mesquite and avoid chemical starters. Light the coals and let them burn until uniformly covered in white ash — about 30 minutes. Can't wait? Use your shop vac with the hose on the outlet as a blower to fan the flames. You'll have red-hot coals in just a few minutes, but be careful — don't blow hot embers all over, go easy!

MAKE: RECIPE

YAKITORI (CHICKEN ON SKEWERS)

Combine mirin, soy sauce, sake, and sugar in a small pan and boil over medium heat until slightly thickened.

Cut chicken into bite-size chunks or strips. Thread the meat evenly on the skewers, centering on the skewer to fit inside the grill. If using bamboo skewers, soak them in water first to prevent burning. Brush with sauce.

Spread the coals to make a uniform layer along the middle of the trough. Insert the skewers into the holes. Rotate the skewers every few minutes, brushing on more sauce. Repeat until golden brown.

INGREDIENTS

» 1lb boneless chicken thighs, with or without skin
» ¾ cup mirin (sweet rice wine)
» ½ cup soy sauce
» ½ cup sake
» ¼ cup sugar
» Skewers

Gregory Hayes

1+2+3 Stain PVC Any Color

BY SEAN MICHAEL RAGAN

PVC PIPE IS GREAT, BUT IT'S KINDA UGLY — it only comes in white, gray, sometimes black, and clear. Sure, you can paint it, but paint can flake and can screw up dimensional tolerances. Stain doesn't flake or add thickness, so the pieces will still fit together.

⚠ **CAUTION:** Work in a well-ventilated workspace and wear gloves and goggles when handling the solvent or dye.

1. Mix the stain.

Visit makeprojects.com/v/30 for a list of dye-to-PVC-cleaner ratios for red, orange, yellow, green, blue, indigo, violet, brown, and black.

Using your pipette, draw up the required volume of each dye and transfer it to the PVC cleaner container. Be careful not to cross-contaminate the dyes. Note that solvent dyes are very strong; 1 ounce goes a long way.

Close the can lid tightly. Wipe off any stray liquid on the outside of the can. Gently shake for about 15 seconds to mix.

2. Apply the stain.

You can use a holder for the PVC, such as a piece of bent wire hanger. Generously slather the stain onto the pipe using the cleaner can's built-in applicator. Work quickly, smoothing out streaks before they have time to dry.

3. Dry and test.

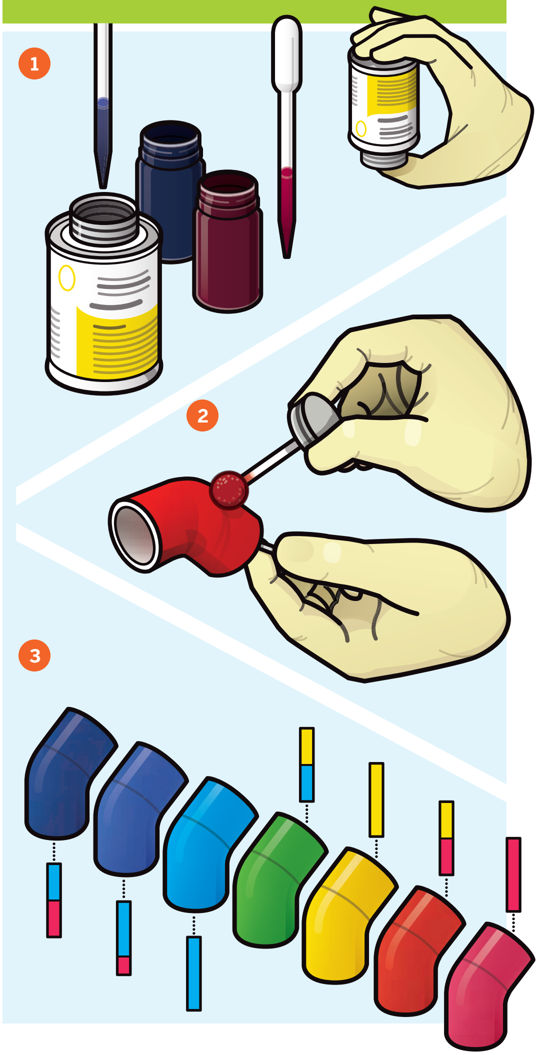
The solvent will dry quickly — an hour will be more than enough. Once dry, the stained PVC should be able to pass a "white glove test" and not transfer even a small amount of color to anything that touches it.

NOTE: Dyes can fade over time; try using light-fast dyes or adding UV stabilizers.

Sean Michael Ragan is descended from 5,000 generations of tool-using hominids. Also he went to college and stuff. smragan.com

YOU WILL NEED

- **Nitrile gloves**
- **Safety goggles**
- **PVC cleaner** Check the label and make sure it contains tetrahydrofuran. I used Oatey Clear Cleaner, a product used to prepare PVC pipe for gluing.
- **Volumetric pipette, measuring 1mL**
- **Solvent dye** I found Rekhaoil Red HF (Solvent Red 164), Rekhaoil Yellow HF (Solvent Yellow 126), and Rekhaoil Blue (Solvent Blue 98) on eBay by searching "petroleum dye."
- **Paper towels**
- **Bent wire hanger (optional)**



Damien Scogin

BEGINNER

IR REMOTE HACKING

How to capture, view, clone, and generate infrared signals.

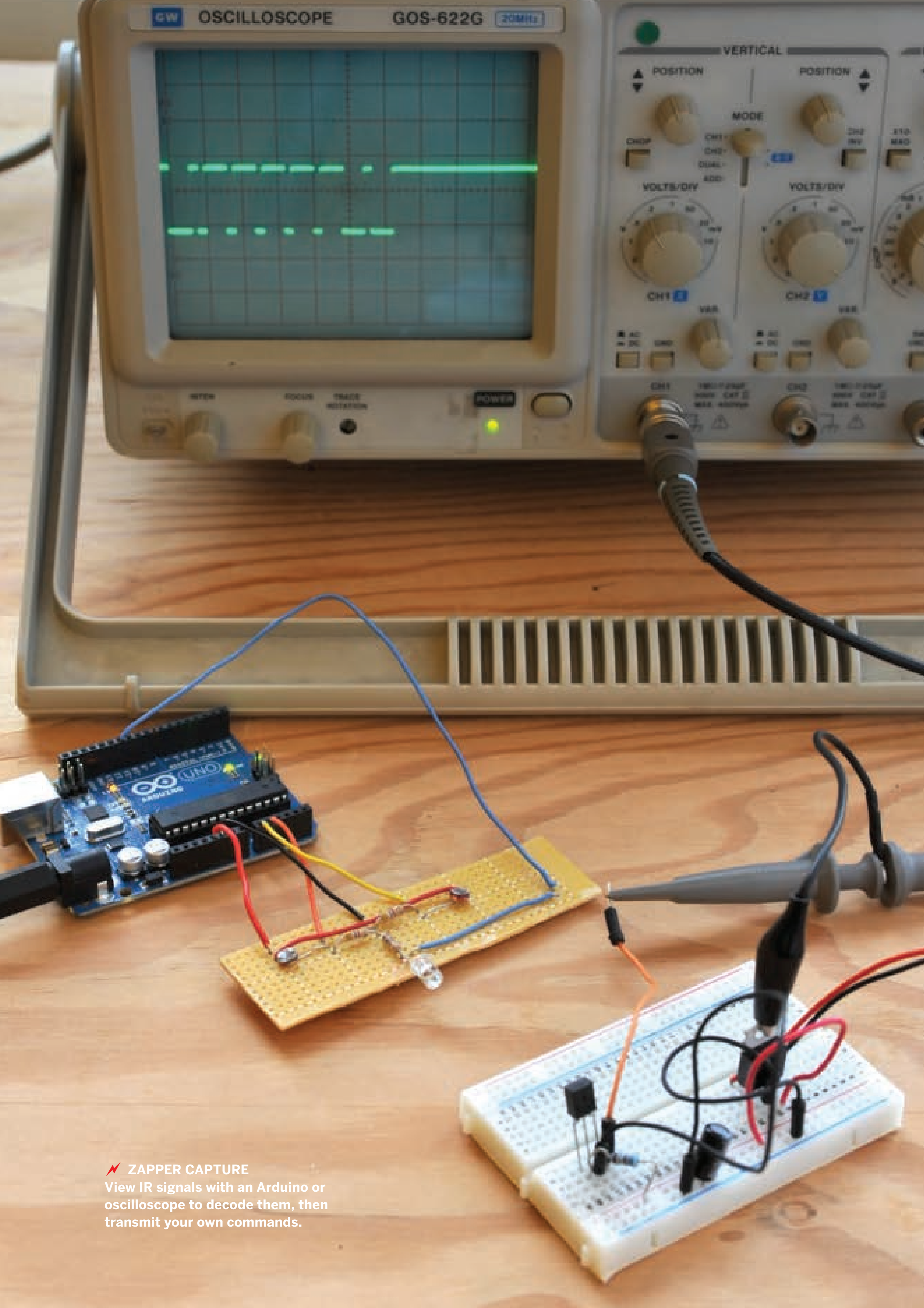
By Tom Lauwers

Infrared signals control an astonishing array of devices. From $20 toy robots to $2,000 3D TVs, the ubiquitous infrared remote has survived the introductions of Bluetooth, wi-fi, and 3G to remain the preferred method of controlling most consumer electronics. As a technology that was developed in the days of disco, it's fairly easy to intercept, decode, and clone IR signals with modern hacker tools, which has led to products both entertaining (like the TV-B-Gone, which turns on or off nearly any TV in sight) and useful (like the RedEye Mini, which controls consumer electronics from a smartphone).

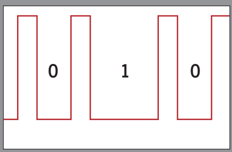
Perhaps because many of us are so used to seeing the remote control as somehow separate from programmable computing, there is something magical about projects that enable your computer or phone to control characteristically "dumb" devices like TVs. But it isn't magic, it's technology, and as any maker knows, technology can be hacked. This article explains IR signals: their structure, how to capture and decode them, and how to transmit them. By the end of the article, armed with an Arduino, breadboard, and $5 in parts, you too will be able to capture and transmit IR signals.

Tom Lauwers is founder of BirdBrain Technologies LLC, maker of the Finch robot and the Brainlink universal robot controller. He resides in Pittsburgh, PA., with his wife, kids, and a small army of robots.

Gregory Hayes

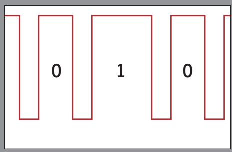


ZAPPER CAPTURE
View IR signals with an Arduino or oscilloscope to decode them, then transmit your own commands.



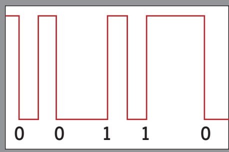
1 Space-Width Encoding

Space-width encodes data in the time between IR light pulses. Each pulse of IR light precedes the transmission of a bit. A short amount of time after a pulse and before the next one represents a logical 0, while a logical 1 is a long period of time between pulses. Space-width encoding is the most common way data is encoded, and is used by most Japanese manufacturers.



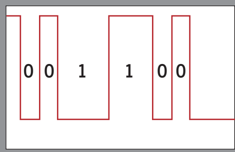
2 Pulse-Width Encoding

Pulse-width (aka pulse-time) encoding focuses on the duration of the pulses rather than the spaces between them. The signal stays high for a variable amount of time, with logical 0 being a short pulse and 1 a long pulse. Time between pulses marks the end of one bit and the start of another. Pulse-width encoding is used by Sony.



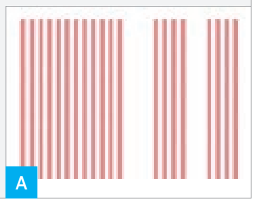
3 Bi-Phase Encoding

In bi-phase encoding, all bits take the same amount of time, during which the signal jumps midway through, either from high to low, which represents logical 0, or from low to high, which represents 1. With consecutive bits of the same value there will be an additional transition between bits.



4 Alternating Encoding

This is the least used but simplest way of encoding data. A logical 1 is a long period of time of either signal value, high or low, and a logical 0 is a short time of signal high or low.



IR SIGNALS, DISSECTED

There is no universal standard for IR communication, and manufacturers use a variety of quasi-standards. Even so, infrared signals all share one common property: they use infrared light to encode digital (binary) data. In our experience, this data is encoded in a signal in one of 4 ways, shown here (above) in rough order of most to least common.

Though these 4 are the primary ways IR data gets encoded, other patterns exist that are manufacturer specific. For example, Roombas use a modified version of bi-phase encoding that looks at a signal-level value (not a transition) in the middle of a bit.

In addition to how data is encoded, IR protocols differ in other important ways:

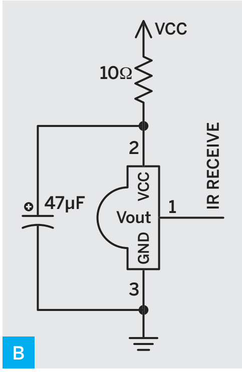
Address pulses and bits: IR signals frequently begin with a long pulse or a sequence of bits that indicate which device the remote control is attempting to control. For example, Sony TV, DVD player, and sound system remote controls encode data in the same way, but to prevent a DVD remote's power button from turning on a TV, each signal starts with a unique address pulse.

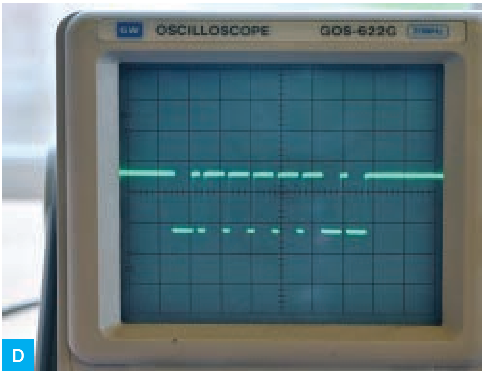
Number of bits: The number of bits encoded per each button-press transmission varies substantially by device — 8, 12, 16, 20, 24, and 32 are all common. Some devices that send 24 or 32 bits of data actually only use 8 bits for information, and use the additional bits for error checking and correction.

Timing: The amount of time a signal goes high or low varies with different manufacturers, with pulses and gaps typically ranging between 500μs (microseconds) and 2,000μs. Most IR remotes transmit data at rates from 250Hz to 2kHz, with the signal timing being the main determinant of bit rate.

Carrier frequency: All IR signals pulse on and off at a carrier frequency that's faster than the bit rate (Figure A). Roughly 90% of remote controls use a carrier between 36kHz–40kHz, and most of the rest use 56kHz. Using a modulated carrier greatly reduces interference from other sources of IR light like sunlight and most artificial lighting. IR receiver circuitry recognizes signals with a certain carrier frequency, and incompatibility issues arise when a remote uses a different carrier than the receiver.

Tom Lauwers





Toggle bit: Several protocols use a "toggle bit" to differentiate between someone holding a button down versus pushing the button repeatedly. When a button is held down, its regular IR signal is followed by alternating 0 and 1 until the button is released.

Space does not allow us to detail each manufacturer's protocol, but understanding the characteristics above will let you unpack the protocol descriptions in the SB-Projects knowledge base at sbprojects.com/knowledge/ir.

CAPTURING AND VIEWING IR SIGNALS

To capture and view IR signals, all you need is an off-the-shelf IR receiver module plus a logic analyzer, oscilloscope, or Arduino. IR receivers are readily available as through-hole components from major vendors like Digi-Key; a typical module is the GP1U from Sharp.

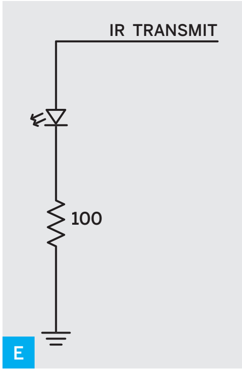
These modules are available pre-tuned to any one of a number of different carrier frequencies, and although receiver datasheets typically specify this frequency to within 0.1kHz, the modules' actual sensitivity can range ±3kHz from spec. This means that you can capture signals from 99% of all remote controls with just 2 receiver modules: one listed as sensitive to 38kHz and another sensitive to 56kHz.

An IR receiver has 3 pins: regulated power (3.3V or 5V is typical), ground, and a logic output, which goes low whenever a signal is detected. The module also typically requires a couple of external passive components to stabilize power. (Figures B and C).

To view IR signals with an oscilloscope, connect its probe to the IR module's output signal and its ground to the probe's ground pin. Power up the circuit, and then take a remote control, point it at the module, and push a button; you should see a signal. Be sure to set your scope's settings appropriately: IR signals are typically between 5ms–20ms in length, and you may need to set up a trigger on a falling or rising edge to hold the signal for inspection (Figure D).

To view signals with an Arduino, connect the output of the IR receiver to Arduino pin 2, and provide the receiver circuit with regulated power and ground from your Arduino. You now need a program that counts rising and falling edges on pin 2 and uses a timer to time the space between edges. Fortunately, the work has been done for you already. I've modified a program found online to create the Arduino sketch *IRReceiverCircuit.pde*, which you can download at makeprojects.com/v/30.

The script waits to detect a falling edge from a GP1U module (keeping in mind that the signal from a receiver goes low when IR light is detected). When it sees a signal, it looks for additional signal transitions, and uses Arduino's timer 1 to count the amount of time between them; the timer has a resolution of 4µs, which is at least 50 times smaller than the smallest valid IR pulse. Every time the program detects a transition, it stores the direction of the transition as well as the current counter time in an array. A timeout



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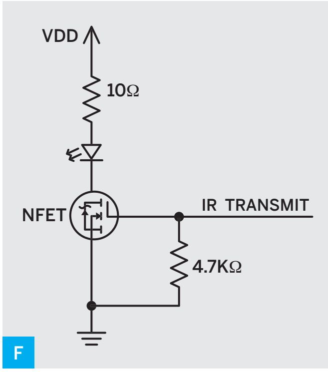

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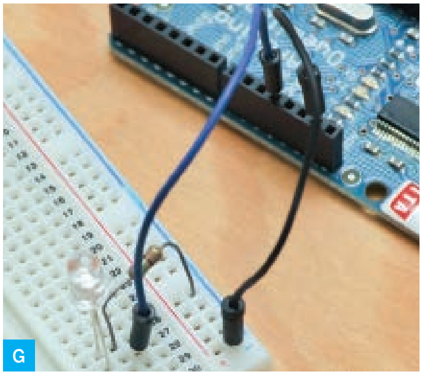

G

allows the program to determine the end of an IR bit stream.

Once the signal has been captured, the program prints the results over serial twice: first as a stream of times between signal transitions (in microseconds), which can be used by a transmission program described in the next section, and then in a tab-separated, time-stamped form that makes it easy to plot using software like Excel or gnuplot.

There are also a couple of commercial tools you can use to capture IR signals. The **USB IR Toy** (dangerousprototypes.com/docs/USB_Infrared_Toy) is a $20 tool that allows you to capture and plot IR signals with carriers between 36kHz–40kHz, as well as clone and transmit signals. It connects to your computer over USB, and accompanying software links to databases of IR codes to let you control most consumer IR devices without capturing the signals first. Additional IRToy software allows you to take the further step of decoding some IR protocols.

Brainlink (brainlinksystem.com) is a universal remote for IR-controlled robots, and is the reason I've become so well acquainted with IR signals. This $125 device allows you to capture IR signals with carriers between 36kHz–40kHz, transmits IR signals, and connects over Bluetooth to your Android phone or computer. Accompanying software will plot and analyze the captured signals and automatically tell you whether they're encoded with space-width, pulse-width, or other encoding techniques.

Brainlink is designed to sit on a toy robot and allow hackers to program it and add new sensors, but it can also be used to control any other consumer IR devices.

TRANSMITTING IR SIGNALS

Transmitting IR signals requires nothing more complicated than an infrared LED and a microcontroller. The circuit is very simple, but there are some characteristics of the LED that you should consider, all of which will affect your transmission distance.

Current requirements: IR LEDs vary greatly in terms of how much current they consume; those that consume more generally transmit farther. If you'd simply like to control your home electronics from 4' or 5' away, you can use the simple circuit in Figure E. If you'd like to make an IR blaster that turns off every TV in sight, you'll need a high-current LED.

Most microcontrollers can only source about 20mA of current from a pin, so this means you'll need to drive the LED with an N-channel MOSFET (Figure F). In both cases you'll need to connect the IR Transmit signal to a microcontroller digital output.

Viewing angle: An LED's viewing angle is almost as important as its current requirement. This spec refers to the angle from the center of the LED at which its light is half as bright as it is when viewed head-on — essentially, how widely the LED's light spreads.

An LED with a narrow viewing angle will need to be pointed somewhat precisely at a device's IR receiver. If you'd like to control several different devices (like a home entertainment system), you want an LED with a wide viewing angle. It's also possible to compensate for a limited viewing angle by connecting several differently angled LEDs in parallel.

Wavelength: IR LED datasheets will list the wavelength at which they are brightest. IR receivers are tuned to wavelengths between 880nm–950nm, so purchase an LED with a wavelength value in this range.

Once you've built your LED circuit (Figure G), you'll need some way to drive IR signals through it. Once again, we've created an Arduino program and example that you can take advantage of. The sketch *TransmitIR Signal.pde*, downloadable at makeprojects.com/v/30, takes a stream of values over serial (you can copy and paste the values directly from the output of our capture program), and then emits the IR signals with a 38kHz carrier frequency on pin 11 of the Arduino.

To change the carrier to 56kHz, simply change the line at the top that defines the variable `OCR2A` or `OCRA2A`. The stream of values sent over serial represents the time between signal transitions; for example, a stream of `500,3000,500,1000,1000` turns the signal on for 500 microseconds, off for 3,000, back on for 500, off for 1,000, and on for 1,000.

DECODING AND ENCODING SIGNALS

The Arduino examples described here capture and use data in a raw time mode. The advantage of this approach is that you can capture any signal without needing to know its protocol. The disadvantage is that each signal is represented by a lot of data — consider that a raw 32-bit signal will typically need 128 bytes of data to represent its time data, versus 4 bytes of data if the protocol is known.

It's possible to decode a signal from its plot and time data. A rough heuristic for doing so would be to:

» Determine the encoding type (bi-phase, space-width, pulse-width, etc).
» Check if there is a start pulse or sequence of start bits.
» Figure out the timing (how long a signal is up or down, and if appropriate, the time to express a logical 0 or 1).
» Go to the SB-Projects knowledge base to check whether this data matches any existing protocols.
» Once the encoding and protocol are known, you can readily begin translating the pulses into logical 0s and 1s.

To then transmit the data, you need to write a program that takes the protocol and the signal's bit values, and then pulses the LED on and off appropriately. Precise instructions depend on the IR protocol for the specific device you're mimicking, but Arduino source code already exists that handles several popular protocols.

JUST AN IR LED AND A MICROCONTROLLER

To start applying your new IR codec abilities, see the "Hack Your Remote" project on page 124, which teaches any device that you can steer with an IR remote (like a Roomba) to autonomously follow a flashlight.

FURTHER READING

To aid you in your IR explorations, I've compiled some resources at brainlinksystem.com/hacking-your-remote-resource-page. The page includes the 3 Arduino programs in this article, suggested parts for capture/transmit circuits, open source Eagle schematics, a layout for a sample (untested) Arduino shield that can use the programs I've created to capture and transmit, a video of a Roomba following a flashlight, and links to even more resources.

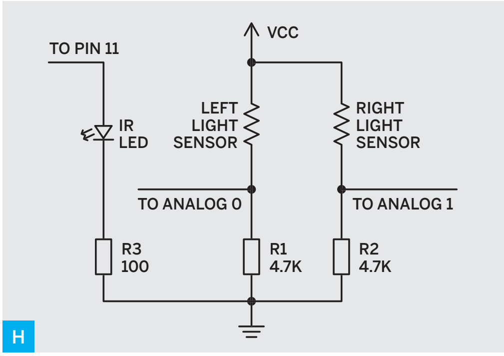
It's everything you need to start your own IR projects, so go hack that TV!

PROJECT BEGINNER

HACK YOUR REMOTE

Putting It All Together: A Light-Following Roomba

One hack that I've enjoyed (and commercialized with Brainlink) is making IR remote-controllable toy robots autonomous. Here's how to make a light-following Roomba by adding an Arduino, IR LED, and 2 light sensors.



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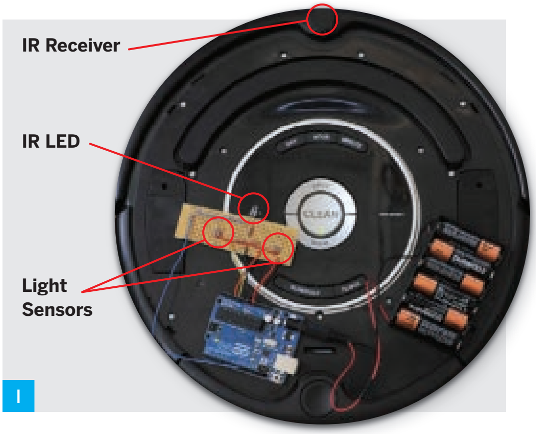


I

» Use the IR capture circuit (Figure B, page 121) and *IRReceiverCircuit.pde* sketch to capture the Roomba signals for forward, left, and right (there is no backward, and stop is just no signal). I simply copy-pasted these from the Arduino IDE's serial monitor into a temporary text file.

» Connect 2 photoresistors and an IR LED to the Arduino: the LED to digital I/O pin 11, and the left and right light sensors to analog input pins 0 and 1 (Figures H and I).

» Load my Arduino sketch *RoombaPhotovore* (download at makeprojects.com/v/30), which compares the values from the 2 light sensors, and sends the appropriate IR signal (turn left, turn right, go forward, or stop). Paste the raw time values captured above into the array definitions in the code for `goForward`, `turnLeft`, and `turnRight`.

» Shine a flashlight on the sensors, observe the readings in the Serial Monitor, and use those numbers to set the values of `LIGHT_THRESHOLD` and `LIGHT_DIFF_THRESHOLD` in the code, so that it can distinguish between the presence and absence of the flashlight beam on each sensor.

Although I used a Roomba, you could use a very similar process to create a light-following Robosapien, a TV that turns off when the lights turn on, and much more.

1+2+3 Sound Sucker

BY WILLIAM GURSTELLE

USING THIS "SOUND SUCKER" DEVICE allows you to experience a curious sensation: it's as if sound is not only being blocked, but actually sucked away from your ear.

The sound sucker works on a narrow range of frequencies. My testing showed it most effective a few cycles to either side of 660Hz (depending on the amount of gelatin), and the effect is most noticeable in a room with a wide spectrum of ambient noise frequencies.

Can you explain this acoustic phenomenon? Or better yet, can you draw a simple diagram? Share your explanation with us at makezine.com/30/123_soundsucker.

YOU WILL NEED

Boiling water
Gelatin dessert mix such as Jell-O, Knox, etc.
Coffee stirrers, plastic, thin, hollow, 5½" long (1 box)
Mug, large, flat-bottomed
Frequency generator (optional) or frequency generator smart-device app
Bowl, spoon, and measuring cup

1. Start cookin'.

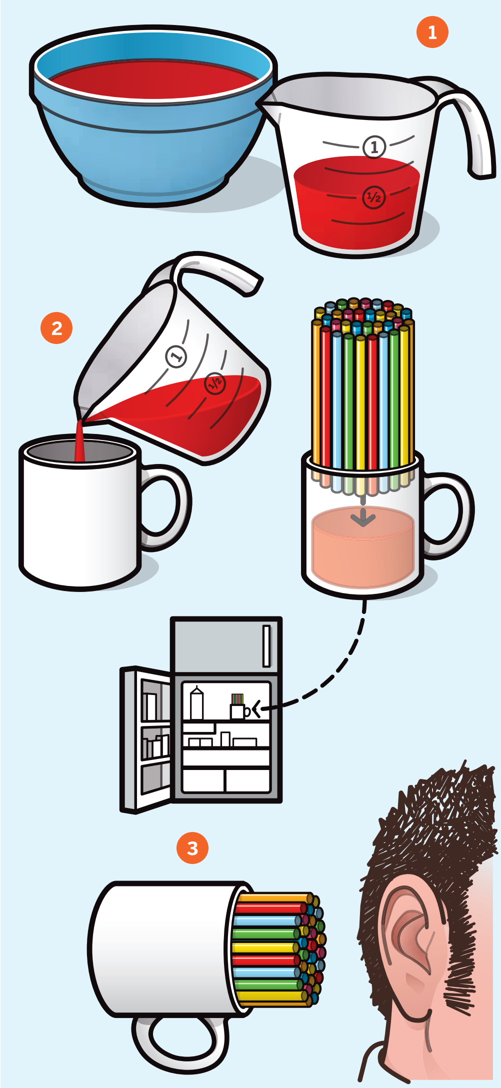
Prepare the gelatin according to the box directions. Before it sets, reserve about a ¼ cup of the liquid for the project.

2. Pack your mug.

Pour the ¼ cup of gelatin into the mug. Place coffee stirrers in the mug, packing it as densely as possible. When done, it looks something like the compound eye of an insect.

3. Let it set.

Place the stirrer-packed mug in the refrigerator until the gelatin sets. The idea is that the gelatin seals the bottom tip of each stirrer.



Suck Up the Sound

In a place with medium-to-loud ambient noise, hold the mug next to your ear, tilted sideways so the opening is facing your ear. If there's enough sound in the 660Hz range, you'll notice a sudden drop-off in acoustic energy (noise) when you bring the sound sucker near.

If you have a frequency generator, test a range of frequencies. Besides the 660Hz tone, it also attenuates some higher frequencies.

MAKE Contributing Editor William Gurstelle is the author of the Remaking History column on page 170 and DIY books including *Backyard Ballistics* and *The Practical Pyromaniac*.

Damien Scogin

Go, Supercap Racer, Go!

Maker Shed's new kit. Build it, juice it up, and let 'er rip!

By Marc de Vinck

THE SUPERCAP RACER IS FAST, FURIOUS, and fun to build. Plus, it's a great way to hone your soldering skills.

This kit was born out of a chance meeting in 2011 at Maker Faire Detroit. I was in the Maker Shed store when George Albercook walked in with a bag of projects he'd been working on. I'm a big fan of checking out anyone's prototypes, and these looked particularly interesting.

All of George's projects had a common theme of education, and more importantly, play. This cobbled-together little "bot" was by far my favorite. It consisted of a few familiar parts, all held together with hot glue. George plugged his tiny contraption into a battery pack for just a few seconds, and zooooom! Off it went flying around the table. I was hooked, and I realized it would make a perfect kit. All we had to figure out was how to manufacture it.

And what to call it. We tried a dozen names, centering around the term "bot." But it isn't really a robot at all. Finally MAKE Projects Editor Keith Hammond blurted out "Supercap Racer." That was it; George's hot-glued prototype had a name, and I had a product to manufacture. The result is this fun kit that's perfect for anyone wanting something to build after they learn to solder.

1. Get ready to solder.

First, check the kit's contents against the bill of materials at makershed.com/supercap.

Marc de Vinck

MATERIALS

Mintronics Supercap Racer Kit (right) from the Maker Shed (makershed.com/supercap). Includes:
- **Custom printed circuit board (PCB)**
- **Supercapacitor, 5.5V, 0.22F**
- **Power cable and matching plug**
- **Battery holder, 4×AAA**
- **Switch, micro lever**
- **DC motors, micro (2)**
- **Rubber caps (2)** for wheels
- **Wire, insulated, a few inches** for "tail"

Batteries, AAA (4) not included in kit

TOOLS

Soldering iron and solder
Wire cutters and strippers
Sandpaper, small piece

Turn your soldering iron on, making sure it's hot and ready to get to work.

2. Mount the motors.

Solder the 2 motors to the PCB at the locations marked "Motor A" and "Motor B." Start by adding a small amount of solder to the small square pads where the tabs of the motors will sit on the PCB (circled in red in Figure A). This is called pre-tinning the pads.

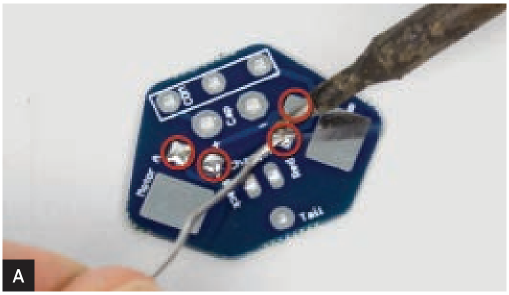
Next, while holding the motor in place, heat the small metal tab of the motor, melting the solder on the PCB and making a connection to the motor's tabs (Figure B).

For added durability, solder the motor holder to the PCB on the outside edge. No need to solder it on both sides of the motor. Just a small "tack" on one side will be strong enough (Figure C).

3. Mount the switch.

Insert the switch's leads through the PCB, from the same side that the motors are mounted on. The switch needs to be oriented as shown in Figure D: the "hinge" part of the switch should be on the left side when looking at the PCB from the front.

Flip the PCB over and solder the switch leads on the back (Figure E, following page). You might have to hold the switch firmly so it lays flat against the PCB. It can be a little tricky. If the switch isn't sitting flat once you



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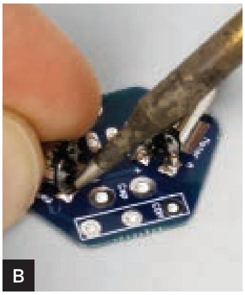
NOTE: Don't overheat this connection, and make sure the tip of the soldering iron touches the PCB and the motor holder.



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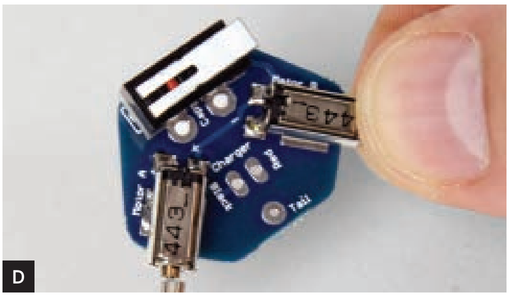


D

solder it on, simply heat the solder up and reseat the switch. Once soldered, trim the leads of the switch close to the PCB (Figure F).

4. Add the supercapacitor.

Insert the supercap into the back of the PCB as shown in Figure G. Make sure its negative (–) lead, marked with the black stripe, is inserted into the hole marked with a (–) sign.

Flip the board over and solder the supercap in place from the front of the PCB (Figure H). Then trim the leads.

5. Solder the power connector.

Now you'll add the power header. The connector should be attached to the wires in your kit. You can see how its halves can be disconnected in Figure I. For now, keep them attached.

Insert the connector from the front of the PCB, with the red (+) wire on the right, where the PCB is labeled (+) too. Flip the PCB over and solder the connector to the board. The connection will be close to the supercap, but there will be just enough room to solder it in place. After soldering, trim the leads (Figure J).

6. Add the tail.

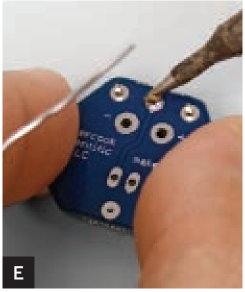
This little racer needs a tail for stabilization. Strip off about ⅛" of insulation from the piece of wire, and insert the stripped end from the back of the PCB (Figure K). Solder it from the front, and trim it flush.

Last but not least, add some character to the tail. I formed mine into a nice curve. The Supercap Racer's movement is highly dependent on the position of its tail. Try different shapes and see what happens.

7. Mount the wheels.

The rubber caps make great wheels; you just need to trim them a bit shorter. Measure about ¼" from the rounded end, and cut them with your wire cutters (Figure L).

Push the part with the rounded end onto the motor's shaft (Figure M). Don't push them too far — if the rubber hits the motor's body then the wheels won't spin.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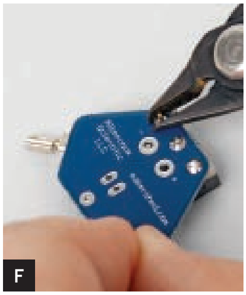
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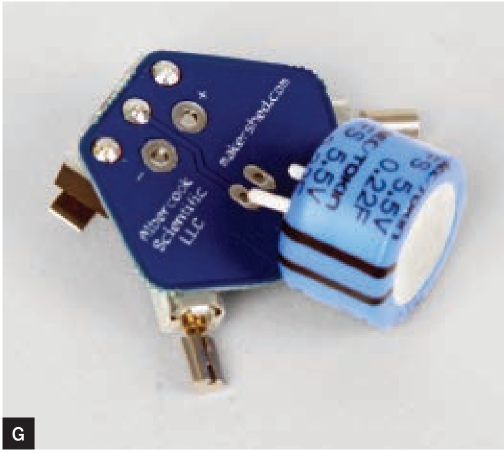
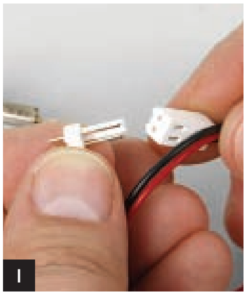


G

NOTE: The supercap shown here happens to have a negative lead longer than its positive, which is the opposite of most electronic components. The capacitor in your kit might have different leads, but the one indicated by the stripe will be the negative (–) lead.


H


I

J

8. Connect the battery pack.

Strip and twist the ends of the power connector's wires (Figure N).

Sometimes there's a slight coating on the contacts of the battery pack, so it's always best to give these a light sanding before soldering. This will help make the connection.

Now solder the red (+) wire to the left terminal and the black (–) wire to the right terminal (Figure O). That's it — you're done!

9. Charge it and go!

To charge the Supercap Racer, simply plug in the battery pack (it only fits one way) and hold down the switch for 10–20 seconds (Figure P).

Next, unplug the power supply while still holding the switch. Place the racer on a flat surface and let it go!

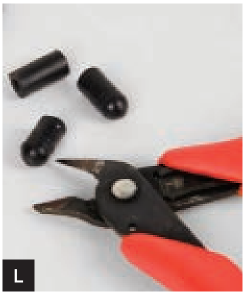
Try bending the tail to make it go in a different direction, or charging it a little longer to go faster. Want to make a mess? Try running your Supercap Racer through small amounts of paint placed on paper. Don't use too much paint, as you don't want the motors getting clogged up. Have fun!

See video of the Supercap Racer build and more photos at makeprojects.com/project/s/1659.

For the Supercap Racer and other great MAKE kits in the Mintronics series, like Blinky POV, Mintduino, and the Survival Pack, visit makershed.com.

Marc de Vinck is director of product development for the Maker Shed.


K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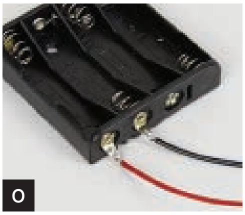
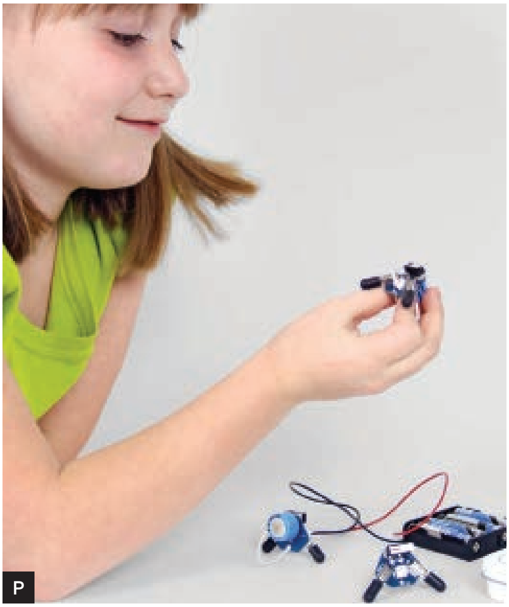
M


N


O


P

Stickstand

Go hands-free and mount your tablet on a monopod.

By Tara Wheeler

THE STICKSTAND IS A PLATFORM THAT mounts an e-reader (in this case an iPad) to a monopod by means of a quick release. It can easily attach to table legs, chairs, or just about anything you can get a loop around, and can be adjusted to a better height and angle for reading.

I also use my Stickstand to turn my iPad into a handheld, mobile, lit sign (mostly to get autographs from celebrities). It works equally well as a display in a booth or in any number of attention-grabbing situations.

The Stickstand is designed to hold an e-reader secured in a folio-type case for added security, so it's got a strap to hold the case's cover flap. If you're not using a folio-type case, make the corner straps tighter and use care when moving the Stickstand with the e-reader in place.

1. Cut a suitable backing plate to size. You can use either a piece of aluminum cut to fit the e-reader, or for the iPad, the heat sink cover plate from a Power Mac G5 with the curved edges cut off is a perfect fit and looks cool.

Sand the cut edges smooth.

2. Drill holes for the straps using a 1⁄16" drill bit. At each corner, drill 2 pairs of holes approximately 1" from the corner in either direction, no more than ½" apart.

At each top corner, drill an additional pair of holes closer to the corner for the flap strap.

3. Position the quick release. Mark the backing plate 1½" down from the top edge, centered, then drill a ¼" hole at your mark.

Countersink all holes to remove sharp edges.

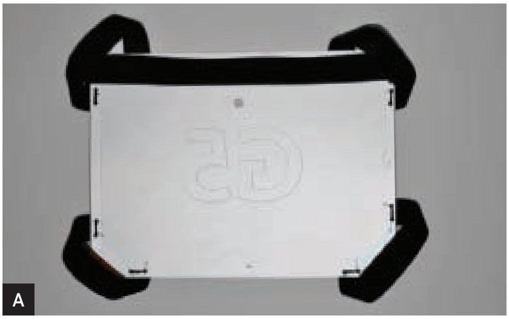
Gregory Hayes

MATERIALS

Aluminum sheet, about 22 gauge about the same size as the footprint of your tablet computer or e-reader. For an iPad, you can use the heat sink cover from a Power Mac G5.
Wing nut, ¼", nylon
Non-roll elastic, ¾" wide, black, 1 yard
Craft foam sheets, 9"×12", 6mm, black (2)
Craft foam sheet, 9"×12", 2mm, black
Velcro, 1" wide, double-sided, black, 2 yards
Monopod ball-head, with quick release plate

TOOLS

Drill, with ¼" and 1/16" bits and countersink
Scissors for cutting foam sheets
Tinsnips for cutting aluminum and wing nut
Sandpaper
Pencil
X-Acto knife
Needle and nylon thread, black
Hot glue gun or flexible epoxy
Cyanoacrylate glue aka super glue or crazy glue


A


B


C

4. Cut the foam to fit the plate: two 6mm pieces and one 2mm piece. Hot-glue the 6mm pieces together and set the 2mm piece aside.

5. Cut straps from the yard of elastic: 1 piece 11" long for the flap strap and 4 pieces 5¾" long for corner straps. Super-glue the cut edges to keep them from unraveling.

6. Sew the straps to the backing plate with black nylon thread, stitching through the holes you drilled. Make about 25 stitches for each end. Start with the flap strap and then sew the corner straps over it (Figure A).

7. Put the glued-together foam on the plate. Make sure your e-reader fits under the corner straps with the foam in place. It should fit securely, but not be difficult to secure. If needed, re-cut the straps and re-sew them.

8. Remove the e-reader and stick a pencil through the ¼" hole from the back to mark the foam. Remove the foam and use the X-Acto knife to cut out a 1"-diameter circle around your mark.

Hot-glue the foam to the plate, centering it over the ¼" hole and aligning the edges flush.

David Wheeler

9. Attach the quick release plate to the backing plate, fastening the wing nut through the hole you cut in the foam (Figure B).

10. Check the placement of the quick release plate in relation to the monopod's ball head. It should click in and out easily, in approximately the orientation you'll primarily be using it. (You'll make fine adjustments later, using the ball head.)

11. When the quick release is in the right position and the wing nut is tight, use snips to cut off the wings.

12. Glue the 2mm piece of foam over the other 2 pieces, covering the hole with the wing nut.

13. Cut the double-sided velcro in half, making 2 straps. Secure the e-reader in the holder (Figure C), attach the quick release to the monopod, and then use the double-sided velcro to attach the Stickstand to a table or chair.

Tara Wheeler owns a full-sized TARDIS prop, knits Doctor Who scarves continuously, tinkers with her website, wittylittleknitter.com, and loves, loves, loves her iPad.

Steve Hoefer

The Eternal Flame

Build simple, nearly indestructible LED lanterns.

By Steve Hoefer

IF YOU'RE LIKE ME, YOU'RE THE BANE OF hardware store employees. I wander through the whole place picking up everything, looking at possibilities more than parts. Can they help me find anything? "No thanks," I answer. What am I working on? "I don't know yet," I say. They move on, keeping a suspicious eye on me.

Some things just seem useful, even if I can't think of how at the moment. One time I found matched pairs of PVC caps and plugs that fit together into little airtight pods of various sizes. For what, I didn't know — until I wanted a way to float lit LEDs down a stream.

The result: simple, rugged, floating LED lanterns that glow for days. They've survived being submerged for a week, frozen, and laundered in the washing machine. I even hit one with the lawn mower, and it still works. When they get dirty, just hose them off.

1. Drill the hole for the LED.

Drill a hole in the top center of the cap using a ⅜" bit; it's just under 10mm and will make a watertight fit for the LED.

Use a drill vise to prevent kickback. To protect the cap from scratches, you can line the vise jaws with tape or cut a V in 2 pieces of scrap wood (Figure A).

2. Prepare the LED.

Cut about ½" (13mm) off the end of each LED lead, so they'll fit easily inside the lantern. Use pliers to bend a small dogleg in the longer, anode (+) pin. This will keep the shorter, cathode (–) pin from accidentally shorting out the side of the battery.

Finally, for watertightness, put a single wrap of thread sealing tape around the base of the LED (Figure B).

MATERIALS AND TOOLS

Pipe fittings, PVC, slip-fit, 1": cap (1) and plug (1) parts #447-010 and #449-010, pvcfittingsonline.com
LED, 10mm, diffused lens any color
Battery, coin cell, CR2032
Binder clip, ¾" wide or smaller
Electrical tape, ½"
Thread sealing tape, ½"
Drill press, drill vise, and ⅜" drill bit
Pliers, slip-joint or other blunt-nosed pliers
Wire cutters

3. Insert the LED.

Place the LED in the pliers so that their blunt nose is flush against the bottom of the LED lens (Figure C). This will let you push the LED firmly without mangling it. Push the LED through the cap from the inside until it's flush with the inside of the cap. If the fit is too tight using just your hands, use the open end of the plug as a backstop and gently tap the handle of the pliers with a rubber mallet.

4. Insulate the binder clip.

The enamel coating on the binder clips can insulate but tends to chip. To avoid shorting out your LED, apply electrical tape insidethe clip. The pliers can help hold it open (Figure D).

5. Power on.

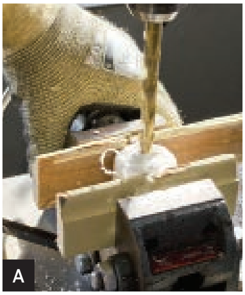
Slide the coin cell battery between the 2 LED leads, with the smooth (positive) side against the longer lead. The LED should light up. Clip the binder clip over the top to hold the leads securely to the LED (Figure E).

6. Close it up.

Wrap the top edge of the plug once with a strip of sealing tape to keep any water out. Then squeeze the plug into the cap (Figure F).

If you plan to use the lantern in water, make it easier to retrieve by drilling a small hole in the edge of the plug and tying in some fishing line. The lanterns tend to float upright; but if you want them to sink, add some fishing weights or steel nuts before final assembly.

When the battery or LED has reached the end of its useful life, a firm twist will loosen the assembly for replacement.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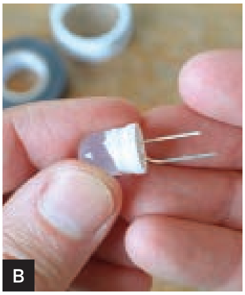
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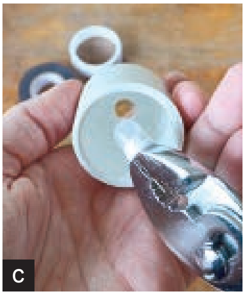
TIP: You can remove unsightly factory markings from PVC with a rag soaked with acetone.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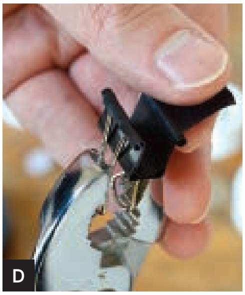
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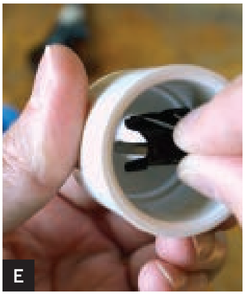
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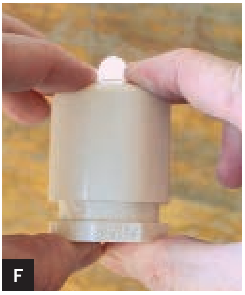
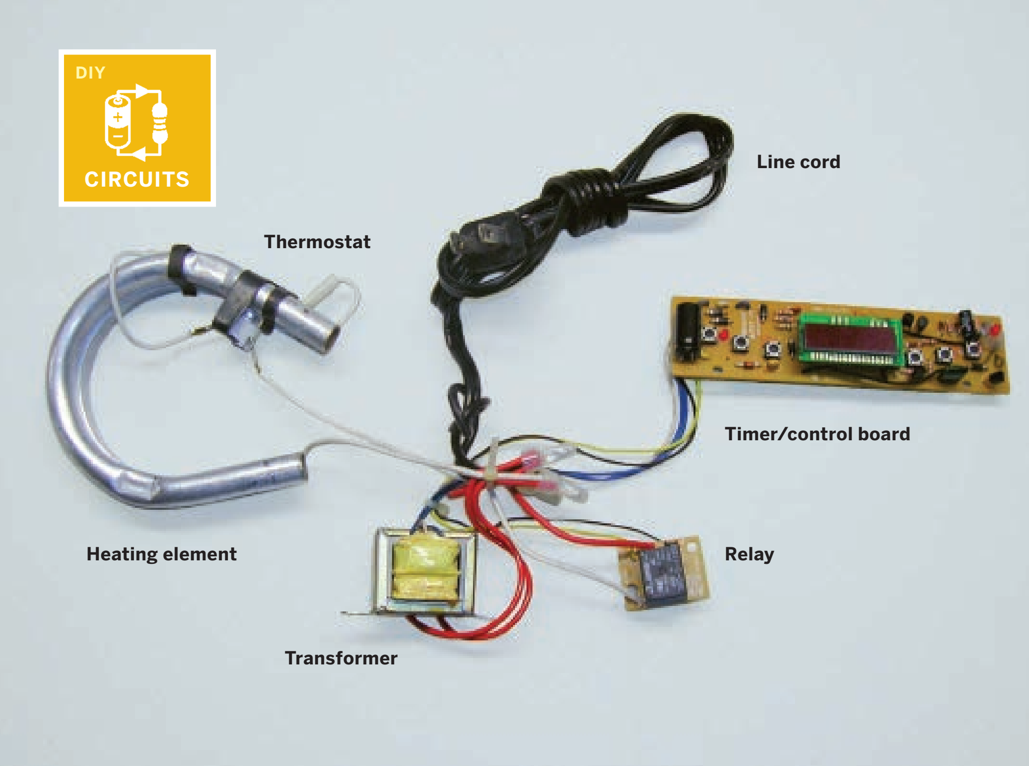

F

7. Illuminate.

Use your LED lanterns anywhere you'd like some durable illumination. They're better in large numbers, and you can vary them to get interesting effects by using flickering or color-changing LEDs.

I've used them to light up a yard party and to mark the trail for night hiking. I've floated them downstream, frozen them in ice, even used them as ammo in a pneumatic cannon. What you can use them for is limited only by your imagination.

Steve Hoefer is a technological problem solver in San Francisco. He spends much of his time trying to help technology and people understand each other better. grathio.com



Mr. Coffee Autopsy

Scrounging parts from a dead coffee maker.

By Thomas J. Arey

JUST LIKE A BOX OF CHOCOLATES, WHEN you're scrounging for castoff electronics and appliances, you never quite know what you're going to get. Take the ever-present home drip coffee maker. I came across one on a recent trash trek (Figure A). It seems that people toss them out when they break the brewing carafe, even though everything else about the unit remains serviceable. Wasteful behavior like this is a boon to the tenacious maker.

When I first encountered a castaway coffee maker, I hoped to just find a small pump and solenoid-controlled valves — a miniature version of what I encountered in my "Clean Out a Dishwasher" article (*see MAKE Volume 08, page 146*). I was surprised to find a much more elegant system inside this coffee machine. Taking it apart revealed a water reservoir, a heating element, and a mechanism for turning the heating element on.

Water is released from the reservoir into a metal pipe atop the heating element. A simple plastic one-way valve keeps water from returning into the reservoir during heating. The heated water, by virtue of expansion and the bubbles produced by the heating process, rises up into the coffee filter basket and filters through into the carafe. In most cases, this simple heating system is controlled by a timer circuit that works in conjunction with a relay to control the line current, and a thermostatic switch to prevent overheating and control post-brew warming.

No pumps or mechanical valves are involved. So my dreams of using coffee maker parts to power a small desktop "serenity garden" were quickly dispelled (unless I wanted that tiny waterfall to contain boiling water!).

Thomas J. Arey

But makers can always find something useful, so I proceeded with the autopsy to find what I could immediately put to use, and what would go into my cache of parts for future projects.

The electrical "guts" of the coffee maker came out in one connected clump after the removal of a few screws.

Immediately useful for any one of hundreds of projects is the transformer. In most cases of scrounged electronics, you'll find that the transformer reduces standard 110V AC line voltage to something more palatable for low-voltage electronics. Most often you'll see a single pair of wires on the secondary (low voltage) side of the transformer.

If you see 3 wires (like the one shown here), it usually means that the secondary winding is center-tapped — for example, that the voltage across the 2 outer wires would be a certain value but the voltage across either outer wire and the center wire would read half the total value across the outer 2 wires.

Such was the case with this coffee maker's transformer, turning 9V into two 4.5V levels. Some transformers have multiple secondary windings. If the voltage ratings aren't listed on the transformer case, they can easily be determined with a voltmeter.

Also useful for various projects is the relay. This device allows you to switch a circuit on or off with the voltage from another circuit. In the case of the coffee maker relay, the low voltage supplied by the timer circuit would control the higher 110V AC line voltage going to the heating element. Relays have many practical uses, including robotics. It's always good to have a few in your junk box.

I didn't have any immediate plans for the heating element so I freed its thermostatic switch from the clip that attached it to the heater. In the coffee maker, this is used to maintain the carafe's warm state after brewing and to prevent overheating that would damage the unit or cause a dangerous possibility of fire. Again, such a device can be put to work for circuits that warn of high heat conditions.

That brings us to the timer board. Lots of great parts here that could be applied to other designs: 6 momentary switches, 2 LEDs, 4 transistors, 5 diodes, a small digital readout, and the ever-present capacitors and resistors. All good for building fun things. But I backed off stripping the board because, remember, it's a timer board! While it may no longer be used to brew coffee, it can be applied to turn many other things on and off. Coupled with the recovered relay, it can be repurposed to control higher voltage systems as well.

While the overall part count is low, even a castoff coffee maker can light up a maker's eyes like a couple of LEDs.


A

Gregory Hayes

CAUTION: Be careful! If you're not comfortable working with voltages and currents that can harm or even kill, either do not attempt this type of project, or seek assistance from someone who can help you learn the needed skills. Safety first!

T.J. "Skip" Arey has been a freelance writer to the radio/electronics hobby world for more than 30 years and is the author of *Radio Monitoring: The How-To Guide*.

Cellphone Car Ignition

Remote-start your ride from any distance.

By Eric Merrill

THOSE OF US WHO LIVE IN PLACES that get very cold or hot appreciate remote car start systems. My 2012 Ford Focus came with remote-start, but the button wasn't on the main key fob. It came on a separate fob instead and has a range of about 30 feet — who wants that? I decided to make a phone interface, to simplify my keychain and add nearly unlimited range.

The basic idea is to install the fob in the car with an Arduino that's equipped with a cellular shield. When you call the shield from an approved number, the Arduino triggers the fob to start the car. Depending on your fob (and whether you want to break it open), you can physically press its button with a servo, or use a relay to make the connection electrically.

The Arduino draws power from your car's battery while the car is off. To get its 12V down to the 5V that the Arduino needs, I used the guts from a cheap 5V auto charger, which is more efficient than a linear voltage regulator like a 7805. To prevent the system from draining the car battery completely, the Arduino monitors its voltage and shuts off power to the whole box when the battery voltage falls below a certain threshold. The shut-off circuit uses a bistable relay, which stays in its current state until a coil is activated to change it. This prevents power from being consumed by the relay while it stays open or closed.

1. Prepare the power boards.

Build the power control circuit on a small piece of perf board, following the schematic diagram (Figure A). For offboard connections, I used straight pin headers to take female-to-female jumper wires (Figure B).

When the Arduino software detects that voltage to its Analog 2 (Vsense) pin has

Eric Merrill

MATERIALS

Car with remote-start key fob
Arduino microcontroller I used a Duemilanove.
Cellular Shield for Arduino with SM5100B SIM card connector SparkFun #CEL–09607, sparkfun.com
SIM card with cellular service I used a T-Mobile SIM Card Activation Kit, $3 with $10/90 day prepaid service.
Cellular antenna SparkFun #CEL–00290
Power jack, 5.5mm×2.1mm barrel, panel-mount
5V DC charger for cars 12V to 5V adapter
Pushbutton switch, panel mount
Relay, latching, Jameco #2095390, jameco.com
Diodes, 1N4001 (2)
Transistor, 2N3904
Resistors: 1.2kΩ (1), 2.7kΩ (1), 22kΩ (1)
Fuse holder, in-line Jameco #108784
Fuse, 2A to fit fuse holder
Perf board, 12×20 holes or cut larger to size
Project box Mine had a 4"×5.5"×2.25" interior, which was a cozy fit.
Machine screws, #4-40, ¾" long (2) with matching washers and nuts
Standoffs, plastic, 3⁄16" or so (2) You can cut them from plastic tubing or a disposable pen barrel.
Jumper wires, female-to-female, 6" (12)
Headers, straight male breakaway, 24 pins total sold in rows of 40
Hookup wire, 18–22 gauge, insulated, stranded
Velcro tape

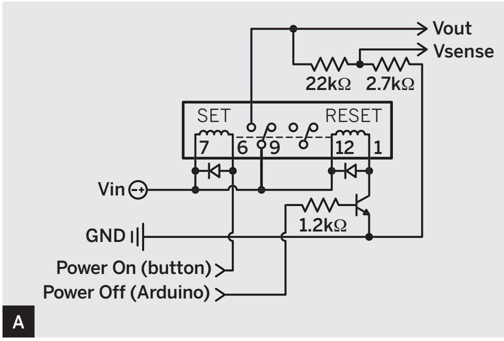
For servo, physical button press:
Hobby servomotor, high torque JR Radios #DS821, jrradios.com
Plywood, ¼" thick, at least 6"×6" or you can use MDF
Machine screws, #6-32, 3" long (4)
Nuts (10) and washers (10) for #6-32 screws

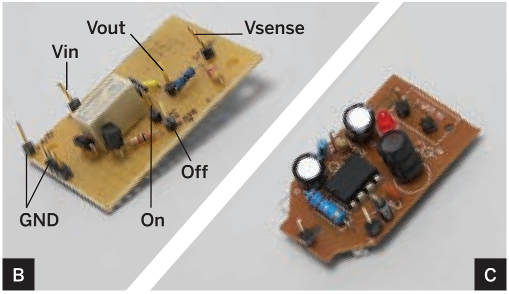
For relay, wired button connection:
Perf board, 12×20 holes or cut larger to size
Relay, 5V, 1A or greater, SPDT or DPDT, DIP package (1 for each button) Maker Shed #JM173914, makershed.com
Transistor, 2N3904 (1 for each button)
Resistor, 1.2kΩ (1 for each button)

TOOLS

Wire cutters and strippers
Soldering iron and solder
Drill and ¼" drill bit
Hacksaw or razor saw
Computer with internet connection and USB port
USB cable or other programming cable for Arduino
Laser cutter (optional)

dropped below a set threshold for a period of time, it sets its Digital 4 (Power Off) pin high. This triggers the relay to cut the power to the entire box. To restore power, press the pushbutton, which activates the other relay coil.





For the power supply board, which converts 12V from the power control to 5V for the Arduino, pop open the 5V car charger and remove its circuit board (Figure C). It should have a 34063 series chip. Save the board along with the 2 power plugs and cable.

2. Prepare the box and base plate.

Cut ¼" plywood to create the base plate, which will hold the Arduino and trigger system. Drill holes to mount the plate to the box's screw points (if present). If you know where you'll be mounting the Arduino and other components, you can drill those holes as well (Figure D, following page). Or for all cutting and drilling, you can download laser cutter templates for my base plate and other plywood pieces at makeprojects.com/v/30.

3. Make the remote trigger.

My remote fob has one button, but with others you hit "lock" before holding down "start." You can keep a one-button remote intact by using a servomotor to push its button. Or with either type of remote, you can use relays to make button connections electrically.

Servo version: Use more ¼" plywood to create 2 small stack plates that sandwich the servo and remote together on top of the base plate, such that the rotating servo arm can push the remote's button. Position the stack on one side of the base, to leave enough room for the Arduino.

I drilled two 2½"×¾" plates and joined them to the base plate using four 3"-long #6-32 screws. To tighten the plates down for holding the servo and remote, I used multiple washers and nuts on each screw (Figure E).

Relay version: Open your remote and examine the PCB inside for the button contacts you want to tap into. There are normally 2 types: intertwined traces that connect electrically when a conductive pad is pressed against them, and mini pushbuttons soldered onto the board. For each button, cut and strip 2 wire leads and solder them to the button's on-board contacts (Figure F). For trace contacts, you may need to gently clean or polish them to get a good solder connection.

Follow the schematic (Figure G) to build the relay circuit on a piece of perf board (Figure H). The Arduino's digital outputs don't deliver enough power to energize the relay coils directly, so they drive them via transistor.

4. Mount.

Mark 2 mounting holes for the Arduino on the base plate, drill with a ⅛" drill bit, and mount the Arduino to the plate over short standoffs using #4-40 screws, washers, and nuts. Fit the cell shield over the Arduino and plug the SIM card into the shield (Figure I).

Drill or laser-cut holes in the project box for mounting the power jack, pushbutton, and antenna jack dangling off the cell shield. Locate these components so they won't get in the way of the parts inside the box, and make sure the antenna jack can reach its mounting hole. I also cut a rectangular access hole in front of the Arduino's USB port, for plugging in the programming cable.

Mount the base plate in the box, and velcro the 2 power boards from Step 1 against the inside back of the box. Solder wires to the power jack and pushbutton, and install them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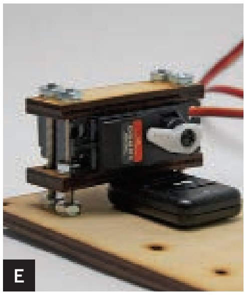
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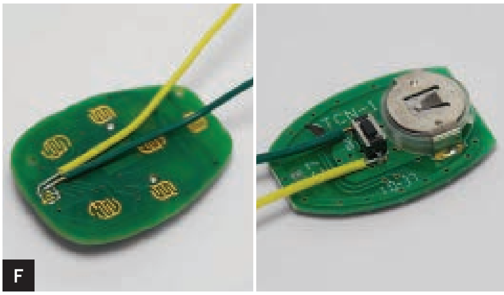
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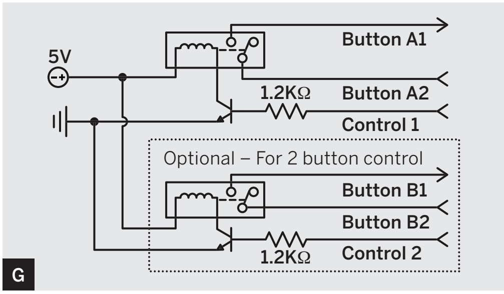

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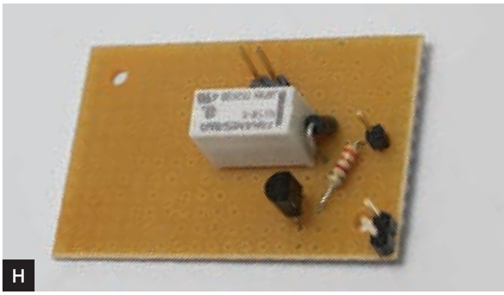
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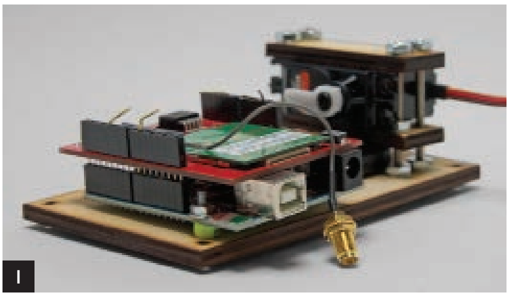
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in the panel along with the antenna jack.

5. Wire.

Follow Figure J to complete the wiring. For a shared ground, connect one side of the pushbutton to grounds from the power jack, Arduino, and power boards. Continue wiring with jumpers to connect the Arduino and remote trigger, connecting either a servo (Figure K) or the relay board and remote (Figure L).

6. Upload the software.

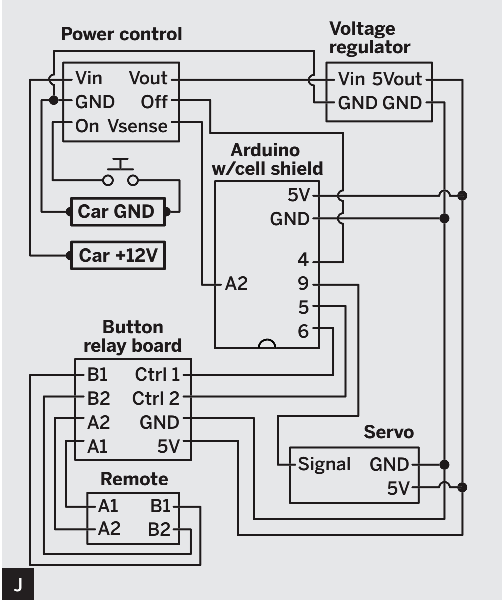
Download code for this project at makeprojects.com/v/30, where you'll also find a link to instructions for uploading it to the Arduino. Comments in the code describe configuration changes you may need to make, for example, where you specify the list of approved phone numbers that you want to start the car from.

The cell shield comes preconfigured to communicate on pins 2 and 3 at 9600 baud, to avoid conflicting with the USB host. The AT command set used with the shield is described at sparkfun.com/products/9607. By monitoring the shield's output, the Arduino can see when any call comes in and what number is calling. To prevent any minutes from being used, the software never picks up a call; it just checks the originating number against the hard-coded approved list.

7. Install.

Installation will depend greatly on your particular vehicle. You need to connect the power plug (from the 5V adapter) to constant 12V power that's always on. In some cars, the regular 12V power port (cigarette lighter) is on all the time. In this case you can simply make a 12V power cable using the 2 plugs left over from the 5V adapter (lighter tip to barrel plug middle, and lighter sides to barrel outside), and connect at the cigarette lighter.

But if your car, like mine, turns the power ports off after you turn off your car, you need to refer to your car model's documentation to identify 12V (+) and (–) wires in the cable harness. Install the box where it can reach both continuous 12V power and your cell antenna mounted outside.



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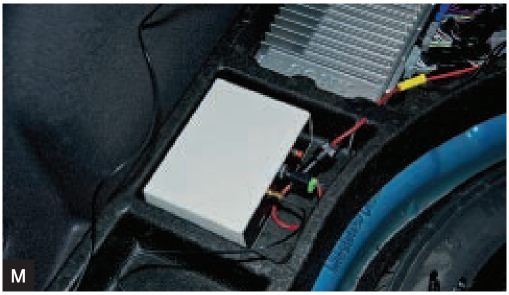
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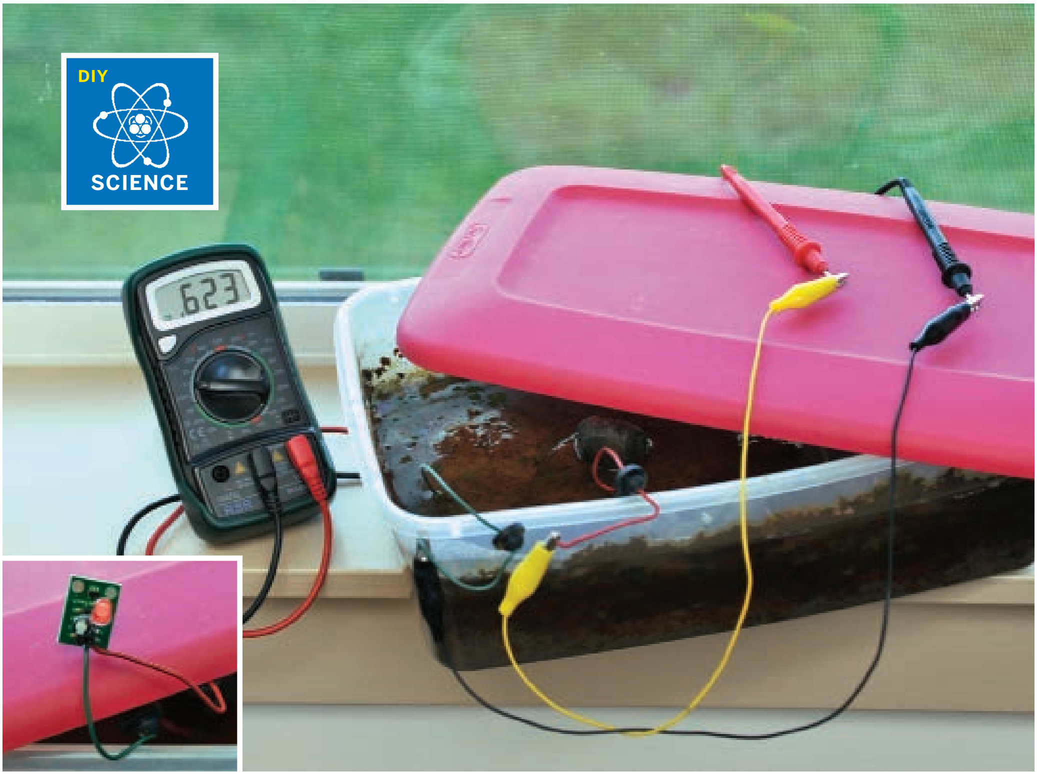
8. Start your engine.

Using your newly hacked remote start is simple — just call the car.

Eric Merrill (ericmblog.com) is a programmer by day, photographer by twilight, maker by night, and CEO of the hackerspace i3 Detroit (i3detroit.com).



Bacteria Battery

Microbial fuel cells generate electricity from "metal-breathing" bacteria in ordinary mud.

By Ashley Franks

MICROORGANISMS OFTEN GET A BAD name because some of them cause disease. But many have useful abilities, from making beer, cheese, and wine to processing waste and cleaning up toxic chemicals. One type of bacteria, discovered in 1987 by Derek Lovley, can generate electricity. Here's how you can find bacteria like these in a local pond and put them to work.

Most non-photosynthesizing bacteria, like all animals, get their energy from the cellular respiration process, which converts glucose and oxygen to water and carbon dioxide. Oxygen works as an oxidizer, which means it accepts electrons as it combines with other chemicals in reactions. But special bacteria underground have no oxygen to breathe. Instead, they produce energy for their growth by transferring electrons to clumps of rust and other surrounding metal oxides, in a process called *dissimilatory metal reduction*. We now know that these electric bacteria are found in mud virtually everywhere on Earth, as well as in soil and compost heaps.

A microbial fuel cell (MFC) does the same thing as a battery: drive electrons from an anode to a cathode through chemical oxidation/reduction reactions. What makes MFCs different is that they run on organic substrate and bacteria.

"Metal-breathing" (*Geobacter*) bacteria at the anode carry out the oxidation reaction, converting plant and animal debris in the mud into electricity and carbon dioxide. Electrons

Gregory Hayes

KIT available in the MAKER SHED

MATERIALS AND TOOLS

MudWatt MFC Kit item #MKKT01 from Maker Shed (makershed.com), $45. Includes all materials below, except mud. You can also build MFCs from scratch, minus the Hacker Board.

- » **Container, waterproof, with tight lid**
- » **Graphite fiber cloth (2 pieces)** sized to fit in container. The kit has 2 rounds, ¼" thick and 3⅝" diameter.
- » **Marine wire, 16–20 gauge, 4" longer than container height (2)** Using 2 different colors helps.
- » **Grommets, rubber (2)** sized to seal marine wire through holes drilled in container lid
- » **MudWatt Hacker Board** includes voltage-boosting chip, 8-pin socket, 22µF capacitor, resistors, and red LED that blinks when bacteria generate power
- » **Gloves** for mixing the mud

Mud Almost any mud with organic compounds will work. Try freshwater ponds or streams, brackish swamps and inlets, or saltwater marshes. Try to find mud that bubbles when disturbed or smells like rotten eggs — both are good indicators of anaerobic bacteria (but don't worry, your MFC won't smell). You can also use soil (just dig down a foot) or compost from the warm middle of a heap.

Drill and drill bit (optional) if drilling your own lids

Multimeter (optional) for testing power

A

flow through wires to a cathode sitting in water above the mud, where they combine with oxygen to complete the circuit. The bacteria are highly efficient in this arrangement and can produce electricity continuously for many months or even years.

Experimental MFC-powered buoys now operate in the Potomac River, using naturally occurring bacteria in the mud to measure and transmit meteorological data (Figure A).

These "Benthic Unattended Generators" (BUGs) have worked for several years with no decrease in power output (see nrl.navy.mil/code6900/bug). *Geobacter* species possess other useful abilities, such as the ability to respire radioactive uranium and remove it from ground water. They have proven versatile and effective in cleaning up areas contaminated with uranium or organic pollutants.

In addition to their scientific interest, MFCs are a useful educational tool: a popular science project that encompasses microbiology, chemistry, electronics, and other disciplines. That's why Keego Technologies developed the MudWatt, a low-cost microbial fuel cell kit.

Anne Keesor (A)

They also support online discussion forums for MFC makers.

With the MudWatt, students of all ages are learning about MFCs and making scientifically relevant discoveries. For example, a 6th-grade student in Santa Cruz uncovered (literally) a river sediment that produces twice as much power as typical topsoil.

Make Your Own MFC

1. Mix your mud (or soil or compost) to saturation with water and put a ½" layer into the bottom of your container. You can experiment by adding extra ingredients; see keegotech.com/community/education for ideas.

2. Cut the 2 pieces of graphite fiber cloth to fit the container. Be careful not to disperse the fibers in the air because they can cause short circuits in household electrical equipment.

Strip 4" from one end of each piece of marine wire, and weave each through a piece of graphite cloth. Strip the other ends ½" and thread each through a grommet. Drill the lid of the container to fit the grommets.

3. Lay one graphite cloth on top of the mud with its wire sticking up; this will be the anode (Figure B). Cover it with ½" more mud and let it settle for a few minutes.

For the cathode, place the other graphite cloth on top of the mud, with its wire also pointing up. Avoid covering the cathode cloth with any mud, and gently pour a little water on top to moisten it (Figure C).

4. Close the container, sealing the grommets into the holes in the lid such that the wires stick out. It may help to gently twist the wires counterclockwise one turn before screwing on the top.

5. Attach the 2 wires to the MudWatt Hacker Board's 8-pin socket: anode to the (–) pin and cathode to the (+) pin.

Microbe Power

Within 3–10 days, the MFC will generally produce enough power to make the LED blink; the more power, the faster the blinking. Keep your MFC warm and moist inside to help the bacteria grow and produce the most power.

The MudWatt Hacker Board boosts the bacteria's power to 2.4 volts, and its 8-pin socket lets you change a resistor value in the blinker circuit to optimize power to the LED. You can also power other devices that run on 3V or less. Download the instructions at keegotech.com/community/Hacker_Booklet and see keegotech.com/forum for more ideas.

Power generated by an MFC is a product of its electrode surface area, so once you have your first one running, don't be afraid to go large (Figure D).

By simply configuring 2 electrodes correctly in mud, soil, or compost, anyone anywhere can harness naturally occurring bacteria to provide continuous, non-polluting, carbon-neutral electricity.

Dr. Ashley Franks is director of K-12 outreach at the Geobacter Project at the University of Massachusetts Amherst (geobacter.org) and a senior lecturer at Latrobe University, Melbourne, Australia (latrobe.edu.au/microbiology/franks).

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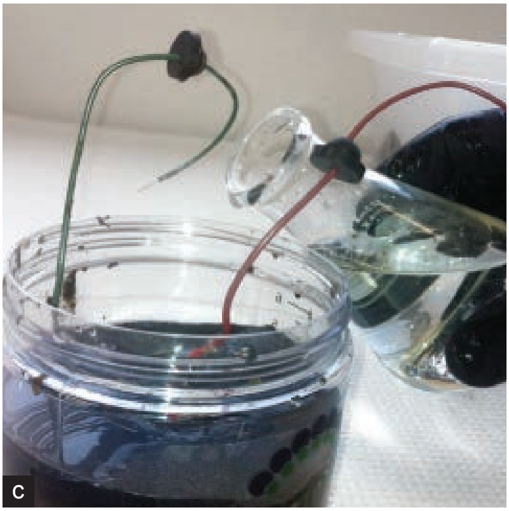

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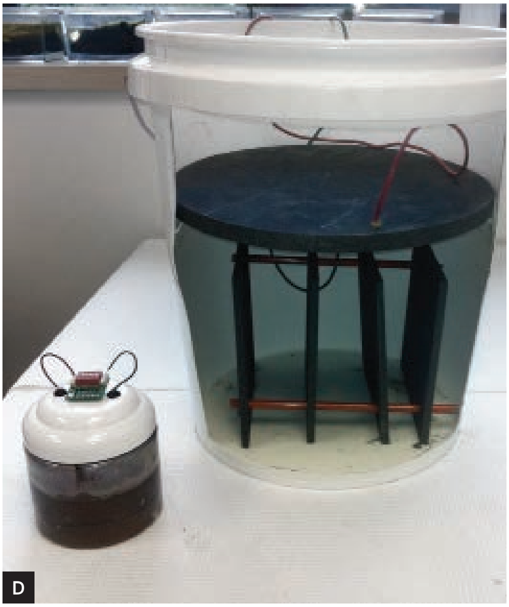

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Ashley Franks (B, D), Manju Sharma (C)

Gregory Hayes

Hydraulic Ram Pump

Clever invention pumps water uphill with more water.

By Matthew Gryczan

HOT-AIR BALLOON CO-INVENTOR Joseph-Michel Montgolfier also invented an ingenious device that pumps water uphill with no external power source. Called the *self-actuating hydraulic ram*, this device is being rediscovered by engineers and social advocates as a simple and sustainable way to distribute water in developing nations.

The secret behind this pump is the "water hammer" — the pressure surge that results when flowing water is halted suddenly.

The ram forks the water into 2 directions. Most flows out through a waste valve, causing it to slam shut. The resulting pressure spike pushes some water through a check valve on the other fork, and into the outlet pipe. The check valve prevents this pressurized water from backing up, so the water is forced uphill through the outlet pipe. The pressure spike also travels back up the inlet pipe and equalizes the pressure there, which reopens the waste valve and restarts the cycle (Figure A, following page).

As with other machines, you've got to give more than you get, and this system can discharge 7 times more water as waste than it pumps. Here's how you can build a desktop version that never fails to fascinate, as it clacks along, pushing water up a small tube.

1. Make the waste valve.

For the waste valve, I used a winemaker's bottle filler; these are rigid wands that let liquid flow through when you stand their weight on a valve pin at the bottom.

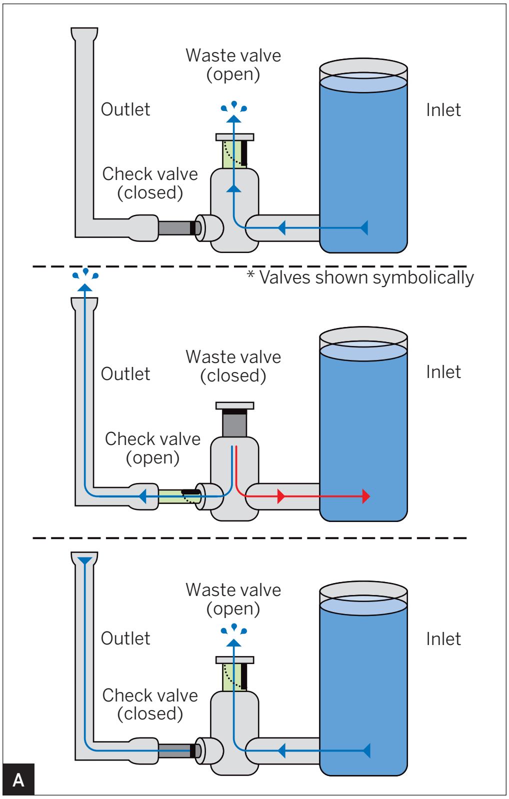
Tape the bottle filler pin in its down/closed position, then drill a ⅛" perpendicular hole through the black valve fitting, centered ½"

MATERIALS

Wine bottle filler, springless valve, with ½" acrylic tube available from Fermtech (fermtech.ca)
Trigger spray top from any consumer spray bottle. I used one from a quart bottle of Clorox Clean-Up.
Tubing, clear flexible vinyl, ⅝" OD, ½" ID, about 3' from hardware, aquarium, or brewing supply stores
Tubing, rigid plastic or metal, 3⁄16" OD, about 3'
Bucket or CD/DVD stack case or other container for water source
Flat plastic tub or other container for catch basin
Rigid plastic sheet, 1⁄16" or ⅛" thick, 2" square such as acrylic (plexiglass) or similar
Assorted nuts and washers or other small metal weights to try as counterweights
Electrical tape
Cyanoacrylate glue aka super glue or crazy glue
Stool or stand to raise water source
Panavise or other way to hold pump above catch basin water line
Ring stand or other way to raise output tube

TOOLS

Drill and drill bits: ⅛", 3⁄16", ¼", 5⁄16", ⅜", 7⁄16", ½"
File, small
Fine-toothed band saw, jigsaw, or razor saw
Hot glue gun
Hot air gun or hair dryer
Vise or wooden vee (optional) to hold pipe for drilling



from its top. Make a pilot punch first and hold the wand in a vise or wooden vee so it stays in place and the drill doesn't wander.

Keep widening the hole with progressively larger drill bits, in 1⁄16" increments, until you have a ½" hole (Figure B). Increasing by larger increments may break the plastic.

With a fine-toothed saw, cut the clear acrylic tube off the black valve and save it for later (Figure C). File the cut end of the valve square and smooth. Clean off any plastic burrs.

At the bottom end of the valve, file the 2 "ears" down flat (Figure D). Scrape away any burrs, and wash the shavings out of the valve.

Mark a ½"×⅜" rectangle on the plastic sheet, drill a ⅛" hole centered inside, and cut it out with a fine-toothed saw. Clean off any burrs and super-glue it to the end of the valve with the pin through the hole (Figure E).

2. Install the waste valve.

Mark a point centered ½" from one end of the acrylic tube you saved, and drill it with a ⅛" bit through *one wall only*. Work your way up to a ⅜" hole, as you did before (Figure F).

Cut the drilled tube to 2", remove burrs, and push it through the hole drilled in the valve (Figure G). Super-glue the tube in place with its hole facing the valve's movable cone.

3. Make the check valve.

My check valve came from inside a spray bottle. Valve styles vary for different products, but here's what worked with a 1qt bottle of Clorox Clean-Up.

Unscrew the spray top, pull off its siphon tube, and save it for later. Open the spray mechanism (Figure H) and remove the ball valve (Figure I). Trim excess plastic on both sides, and hot-glue the valve to the short end of the acrylic tube, oriented to only allow water to run away from the waste valve.

4. Add the input and output tubes.

Drill a hole in the bottom of a bucket or similar container, and hot-glue in one end of a

30" length of vinyl tubing. Make sure the joint is leakproof. Fit the other end over the input side of the waste valve; it should fit snugly.

Gently heat one end of the spray bottle's siphon tube with a hot air gun or hair dryer, and bend it 90° without kinking it. Thicken the end by wrapping it with electrical tape, then couple it to the check valve with a short piece of vinyl tubing, pointing the output tube upward (Figure J). Your pump is complete.

5. Set up the pump and water source.

Use ring stands or other means to raise the pump slightly above a catch basin, to hold the water source about 25" above the pump, and to hold the output tube upright. Fit some stiff 3⁄16" tubing over the output tube to extend it higher than the water source.

Fill the water source. The waste valve should shut, with little or no water exiting, and if you tap it with your finger, the ram should send water up the output tube. Flick it to remove all air bubbles from the output side.

6. Adjust for automatic cycling.

To get the ram to cycle automatically, you'll need to add some weight to the waste valve cover. Try different small weights, and file away some metal to fine-tune the weight down. When you have the correct weight, hot-glue it on and watch the water run uphill.

Going Further

To make larger ram pumps, you can fabricate your own check valves from flaps of plastic, or waste valves out of O-rings and valve seats. You can even scale up to full-sized ram pumps using standard plumbing fittings.

Resources

Make a full-sized ram pump from PVC pipe: clemson.edu/irrig/equip/ram.htm

See video of the hydraulic ram in action: makeprojects.com/v/30

Matthew Gryczan is a former manufacturing engineer and newspaper reporter who has been a lifelong basement tinkerer. In his day job, he writes news releases for science and technology companies at SciTech Communications.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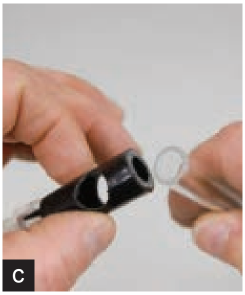
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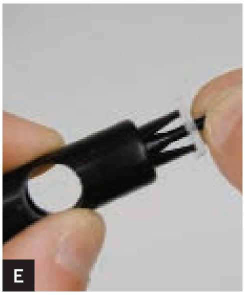
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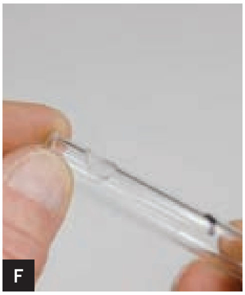
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Matthew Gryczan

COUNTRY SCIENTIST
By Forrest M. Mims III,
Amateur Scientist

USING SENSORS WITH DATA LOGGERS

Data logging is the automatic collection and saving of information. Having the ability to automatically log a string of measurements and save them for later study and analysis can help transform you from an experimenter into a scientist.

Trees are natural data loggers, and I described how to analyze their annual growth rings in MAKE Volume 19. So are layers of snow (Volume 21). And you can log sunlight intensity for entire days using blueprint paper (Volume 26).

Electronic data logging provides an enormous range of opportunities for amateur scientists. Back in the 1980s, I would connect a sensor to the joystick port of a PC like RadioShack's Color Computer or IBM's PCjr, and write simple data logging programs in BASIC. When analog-to-digital interface boards became affordable, my logging became more sophisticated. Still, these methods required a computer dedicated solely to the logging operation.

Data logging changed dramatically when miniature, standalone loggers were introduced. These devices provide real-time logging without the need for a dedicated computer. They're activated and downloaded by a computer, but in between, they operate independently. Data loggers are available from Onset Computer, Jameco, Omega Engineering, SparkFun, and others. Maker Shed (makershed.com) also sells a data logging shield for Arduino microcontrollers.

Interfacing Sensors to Loggers

You can buy tiny data loggers that store temperature readings over time. Other loggers record light, carbon dioxide, pressure, and other parameters. But what if you want to log a parameter for which there is no logger?

You can build your own logging system from scratch or from published plans. Or you can do as I've done and design DIY sensor circuits that can be connected to the voltage input(s) of commercial loggers. This approach frees up considerable time, since software is already available for these loggers.

If a sensor produces an output voltage that doesn't exceed the allowable input voltage for the logger, no circuitry is needed (unless the signal is so small that it requires amplification). A typical logger has an allowable input range of 0 to 2.5 volts. This means you can safely and directly log the voltage of many kinds of disposable and rechargeable power cells and batteries.

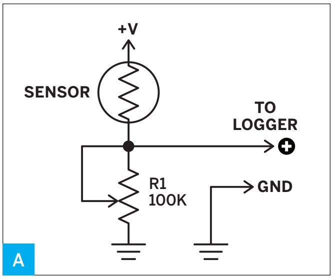
Voltage Divider Sensor Interface

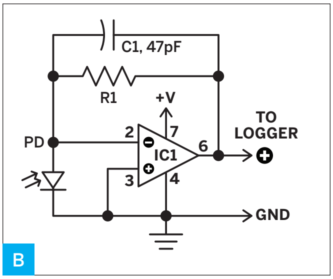
If your sensor is resistive it won't produce a voltage, so you'll need to connect it as half of a voltage divider. The simplest interface circuit for resistive sensors is the single resistor or potentiometer circuit shown in Figure A. It can be used with light-sensitive photoresistors, temperature-sensitive thermistors, and other sensors having a resistance that changes with pressure, touch, weight, acceleration, rotary motion, and so forth.

R1 is a resistor or pot connected in series with the resistive sensor to form a voltage divider. Using a pot allows the sensitivity of the circuit to be easily adjusted. The free end of the sensor is connected to the logger's positive supply voltage, and the free end of R1 is connected to the logger's ground at the input. The junction of the sensor and R1 is connected to the logger's positive input. Be sure to check the polarity of the logger's input before making the connections.

It's best to use the logger's supply to power this interface, since this will avoid applying excessive voltage to the input. If the positive supply isn't available externally, you can open

SURF AND SUNBURN Data loggers showed that Hawaiian surf reflected solar UV-B radiation (see Figure F, following page).





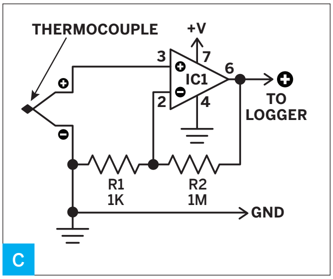


Fig. A: Use this simple voltage divider to connect resistive sensors, like photoresistors and thermistors, to voltage loggers.

Fig. B: Current-to-voltage input for a data logger. PD is a photodiode. IC1 is a single, not dual, op-amp.

Fig. C: Voltage-to-voltage input for a data logger. IC1 is a single op-amp.

the battery hatch or the enclosure and carefully solder a connection wire to the positive (+) side of the battery connection.

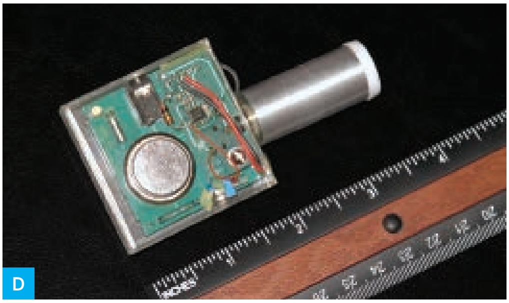
Op-Amp Sensor Interfaces

If your sensor's output is too low for your logger, you'll need to amplify it. Operational amplifiers are ideal for boosting the very tiny current from light-sensitive photodiodes and the voltage produced by thermocouples in response to temperature. Very few components are needed, since most of the electronics are inside the op-amp. For best results, select an op-amp that can be powered by a single polarity supply at or below the operating voltage of the data logger. This allows the sensor interface to be powered by the logger, and ensures that the sensor output won't exceed the logger's voltage.

Many different low-voltage op-amps are made by Maxim, Texas Instruments, National Semiconductor, and others. They're available in both traditional 8-pin mini-DIPs and surface-mount packages, from Jameco, Digi-Key, Mouser, and other distributors.

I've had very good results using the TI 271 with 8-bit Onset loggers. This op-amp requires a minimum of 4V, which exceeds the 3V lithium battery that powers these loggers, so I have to attach a 9V battery to the modified logger. I'm planning a new set of modified

Forrest M. Mims III



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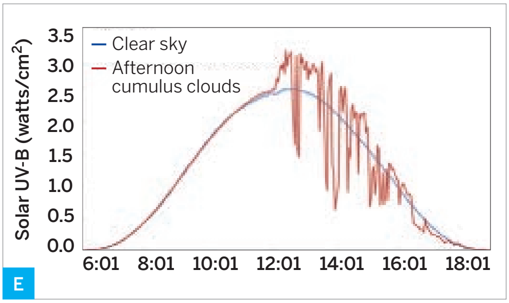

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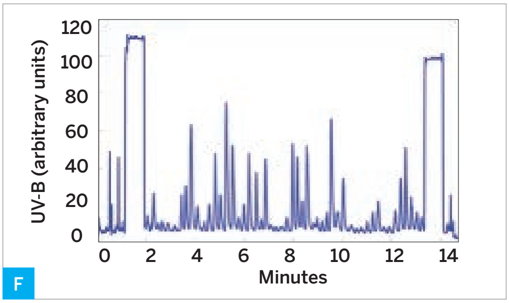

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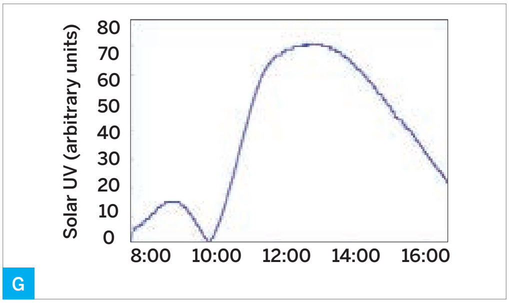


G

Fig. D: Hobo data logger modified with UV detector (aluminum tube with Teflon diffuser cap) and current-to-voltage op-amp circuit on rectangular circuit board above the battery.

Fig. E: Effect of cumulus clouds on solar UV at Hawaii's Mauna Loa Observatory (11,200 feet).

Fig. F: Solar UV reflected from waves breaking on lava in Hawaii. The rectangular spikes at either end of the chart were when the UV detector was pointed upward toward the sun and sky.

Fig. G: Solar UV during the May 10, 1994, annular eclipse of the sun. Peak annularity is indicated by the bottom of the sharp dip in the graph, when for about 5 minutes the only sunlight was a brilliant ring around the moon.

loggers that will use the TLC251, TLC252 (a dual 251), or other op-amps powered by only a few volts.

Some sensors, like photodiodes and photovoltaic or solar cells, produce a variable current at a relatively stable voltage. Figure B (previous page) is a circuit I've used to interface various photodiodes with 8-bit and 12-bit Onset Hobo loggers. The photodiode generates a small photocurrent when illuminated by a light source of the appropriate wavelength. The op-amp converts the current to voltage and amplifies it, so it can be saved by a logger. The amplification or *gain* equals the resistance of feedback resistor R1. Thus, if R1 is rated 1,000,000 ohms (1MΩ), the photocurrent is amplified by 1 million. Reduce R1's resistance if the circuit's output approaches the power supply voltage before the light levels you're trying to record are reached. Increase R1 if the circuit isn't sufficiently sensitive. Capacitor C1 helps prevent oscillation of the circuit.

The circuit in Figure C is for sensors that produce a variable voltage instead of a current. Thermocouples, for example, produce a voltage proportional to the temperature to which they're heated. The gain of this circuit is 1 + (R2/R1). The values shown in Figure C provide a gain of about 1,000, suitable for monitoring the heat from a space heater when used with a type K thermocouple. Increase R2's resistance for more temperature sensitivity.

Some Data Logger Applications

I first began using standalone data loggers to measure the temperature of fire ant mounds, our doghouse, and the cells in a paper wasp nest. These experiments were so interesting that I decided to measure other parameters, especially the sun's ultraviolet and photosynthetically active radiation (PAR), the blue and red wavelengths that make plants grow. No data loggers were available for these applications, so I used the circuit in Figure B together

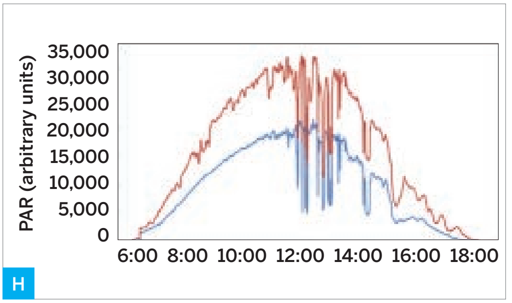


Fig. H: The photosynthetic radiation (PAR) responsible for plant growth on a very smoky day (blue) and a cleaner day (red) at Alta Floresta, Brazil. Sharp dips indicate clouds at the sun.

Fig. I: The sunlight intensity measured by two solar pyranometers at Hawaii's Mauna Loa Observatory is being logged by two of the four channels in an Onset 12-bit data logger.

with various DIY UV and PAR sensors.

The most interesting results from these logging projects came during one of my annual trips to calibrate instruments at Hawaii's Mauna Loa Observatory (MLO). Prior to the trip, I modified 16 Onset Hobo loggers with the op-amp circuit in Figure B and photodiodes fitted with UV-B filters (Figure D).

I hid the modified loggers around the Big Island in places with full sunlight. Several days later I retrieved the loggers, which provided a record of solar UV-B between sea level and the 11,200-foot elevation of MLO. The MLO logger showed that cumulus clouds near the sun caused UV-B increases of up to 15%. Figure E shows the data on a clear day and on a day with clouds during the afternoon. This finding led to a report in a leading scientific journal (F.M. Mims III and John E. Frederick, "Cumulus Clouds and UV-B," *Nature* 371, 1994).

In Hawaii I've also measured the sun's UV-B underwater and reflected by surf. Figure F shows a typical result when the sensor was mounted on a 12-foot pole and held over the surf: significant UV-B is reflected from ocean surf. When I repeated these measurements over a turbulent waterfall in Colorado, very little UV-B was reflected.

During the May 10, 1994, annular eclipse of the sun, one of my modified Hobos monitored the sun's UV-B. During peak annularity, the sun formed a thin ring of brilliant light around the moon for about five minutes. The highly diminished solar UV during this time is indicated by the bottom of the dip in Figure G.

NASA twice sent me to Brazil to monitor the ozone layer and other atmospheric parameters during that country's annual burning seasons. Hobo data loggers modified to measure UV and PAR silently monitored whatever sunlight managed to leak through the smoky sky, allowing me to concentrate on measuring smoke and ozone. Figure H shows the PAR measured at Alta Floresta on a very smoky day and a cleaner day. When I left Alta Floresta for a remote camp on the Cristalino River, a concealed Hobo with a DIY sensor provided an important record of PAR during my absence.

Figure I shows two pyranometers (solar radiation sensors) at Hawaii's Mauna Loa Observatory connected to an Onset U12-006. My recent work with these remarkable 12-bit loggers has led to new findings I hope to publish. The pyranometers were designed by my colleague Dr. David Brooks of the Institute for Earth Science Research and Education (IESRE) and are available as kits or assembled units at makezine.com/go/pyrano.

Get Started Logging

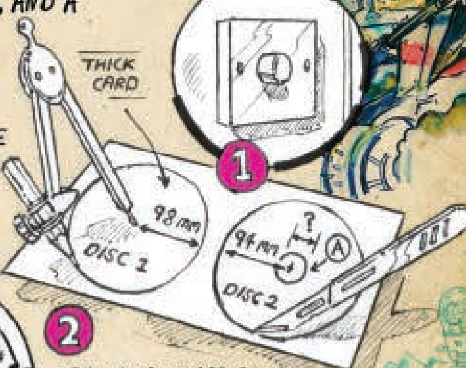
If you want to do serious amateur science, data logging has huge potential. I recommend you acquire a basic temperature-sensing logger and start experimenting. The experience might inspire you to find entirely new logger applications.

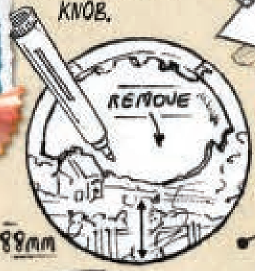
Forrest M. Mims III (forrestmims.org), an amateur scientist and Rolex Award winner, was named by *Discover* magazine as one of the "50 Best Brains in Science." His books have sold more than 7 million copies.

What I made

TURN A DIMMER SWITCH INTO A COOL DAY AND NIGHT DIAL. YOU'LL NEED A ROTARY DIMMER SWITCH, THICK AND THIN CARDSTOCK, GLUE, AND A CRAFT KNIFE.

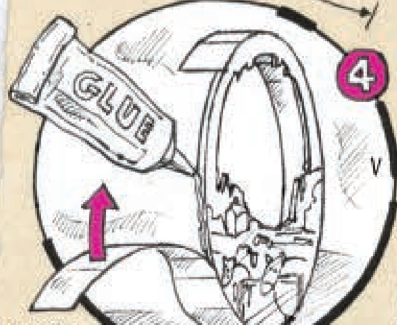
START BY CUTTING 2 DISCS FROM THE THICK CARD. ENSURE HOLE (A) FITS TIGHTLY OVER THE DIMMER SWITCH KNOB.



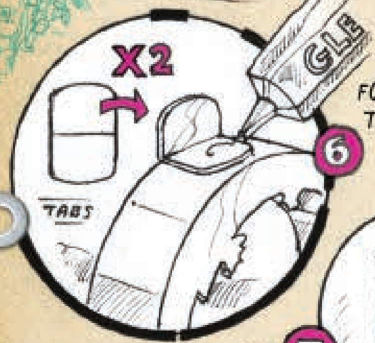


DRAW AN OUTDOOR SCENE ON ONE OF THE DISCS. REMOVE THE SKY AREA USING A CRAFT KNIFE.

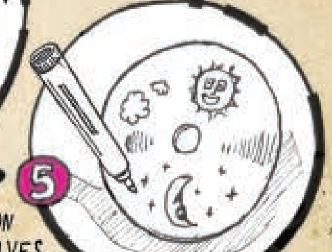
NOW CUT 2 LONG STRIPS FROM THE THIN CARD – THESE ARE THE SIDES.



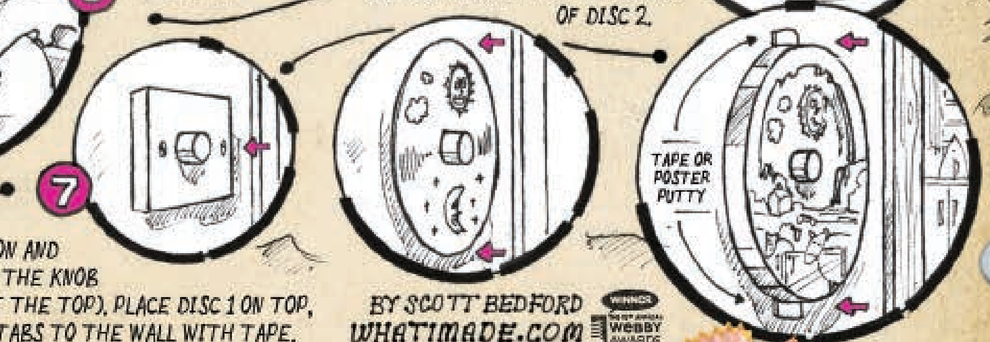
GLUE ALONG THE EDGE OF DISC 1 AND WRAP THE THIN STRIPS AROUND, OVERLAPPING THEM AND GLUING THE ENDS.



CUT OUT 2 TABS FROM THIN CARD, FOLD THEM IN HALF, AND GLUE TO THE TOPAND BOTTOM OF DISC 1.



DRAW A SUN AND MOON SKY SCENE ON OPPOSITE HALVES OF DISC 2.



TURN THE LIGHT ON AND PUSH DISC 2 ONTO THE KNOB (WITH THE SUN AT THE TOP). PLACE DISC 1 ON TOP, ATTACHING THE TABS TO THE WALL WITH TAPE.

BY SCOTT BEDFORD
WHATIMADE.COM


EARN YOUR WINGS!
ELEV-8
Quadcopter Kit
The ELEV-8™ Quadcopter Kit ($599.00) uses a HoverFly board with a Propeller multicore microcontroller to electronically control stabilization of the aircraft. The benefits to this system are a stable platform with no mechanical linkages, for a small, maneuverable, and agile aircraft.
The ELEV-8 platform is large enough for outdoor flight and has plenty of room for payload and attachments (up to 2 lbs). You provide the (6-Channel) RC radio equipment and a battery. Size: 20.25 x 20.25 x 7 inches (514 x 514 x 178 mm)
Assembly required (average 8 hours)
The ELEV-8 kit is not for beginners. A moderate mechanical skill is required to build and fly this quadcopter. Inform yourself of all applicable federal, state, and local laws, and fly at your own risk!
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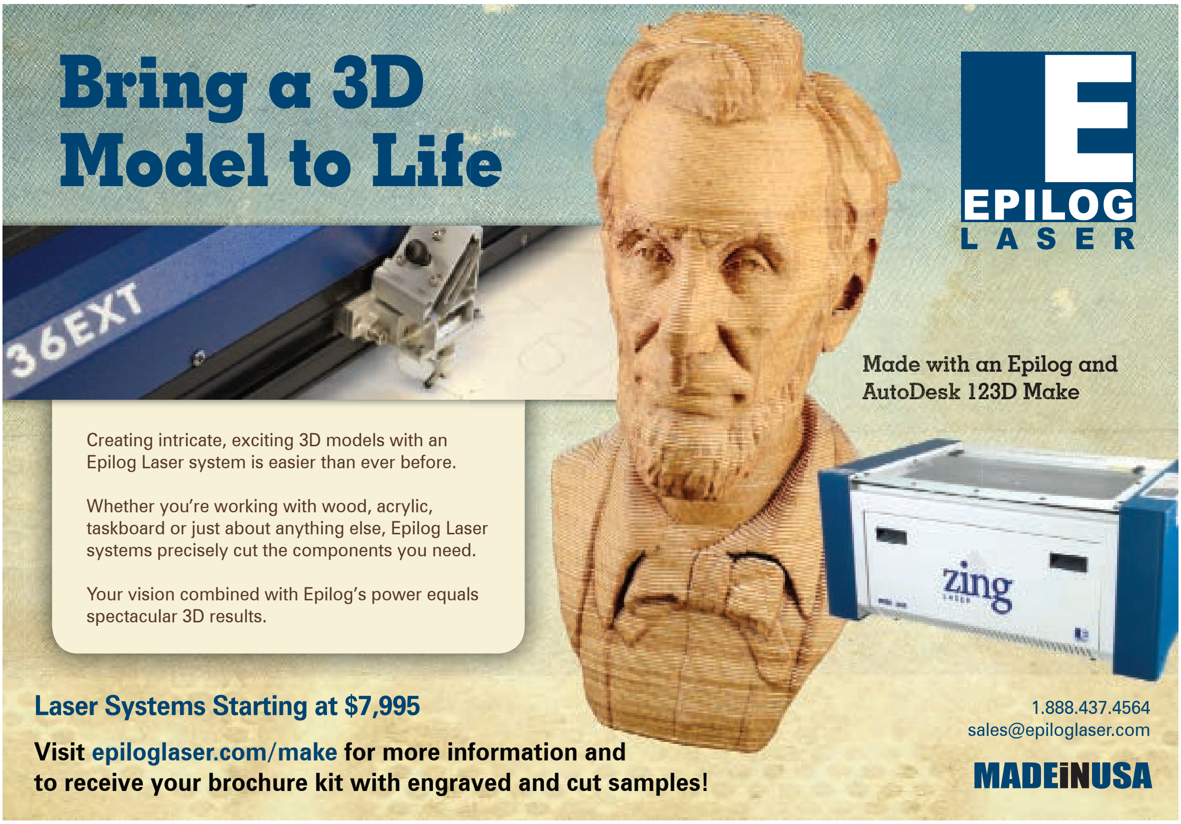
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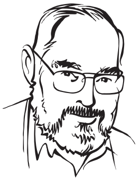


TOYS, TRICKS, AND TEASERS
By Donald Simanek,
Recreational Physicist

THINGS YOU CAN'T MAKE

Simple tricks of illusion make the impossible a reality.

MAKE readers enjoy making things that are useful in innovative or just plain weird ways. Some of these great ideas work well and reach the pages of this magazine. Some just don't work out in the real world. And some ideas are downright misguided.

For a change of pace, having recently neglected "teasers" in these pages, I put some thought into things you simply can't make, no matter how clever and ingenious you are. There are still folks who think, "Anything is possible if you tinker with it enough." Allow me to demolish that naive notion.

Nature behaves according to fundamental laws. We can discover some of these and express them in the universal language of mathematics, elevating them to the status of "laws" of nature. Newton's laws, conservation laws, and most importantly the laws of geometry describe how nature works. There's good reason to suppose that all laws of nature arise from the limitations of the geometry of the universe. When we have formulated and thoroughly tested a law about how nature works and are certain it doesn't contradict other known laws, that same law is also telling us how nature doesn't work.

Another diabolical thing about nature is how interrelated its basic laws of physics are — you can't violate one of them without violating many others. Nature blocks us from violating any one of its fundamental laws, those that are so thoroughly tested that they will likely survive any future advances in science.

Futile Projects

Can you cut a triangle from a flat piece of paper that has exactly equal sides but unequal angles? Silly idea, you say. That would violate laws of Euclidean geometry, and we know that our neighborhood of the universe obeys Euclidean geometry at least to the precision that we are capable of measuring.

Can you design a walking path that is downhill all the way around — in either direction, clockwise or counterclockwise? It's an old joke: "When I was a kid I had to walk 2 miles to and from school everyday, uphill both ways." We laugh because we know it's impossible. This says something about the laws that operate around closed paths. Perpetual-motion machine inventors ought to take this seriously.

Could you cut from wood a cube with 7 faces? That violates the logical definition of a cube. That's like making a 4-sided triangle. But a sphere with surface area of only 4 times the square of its radius is another class of impossibility, one that isn't merely a logical paradox, but a violation of a geometric property of the real world.

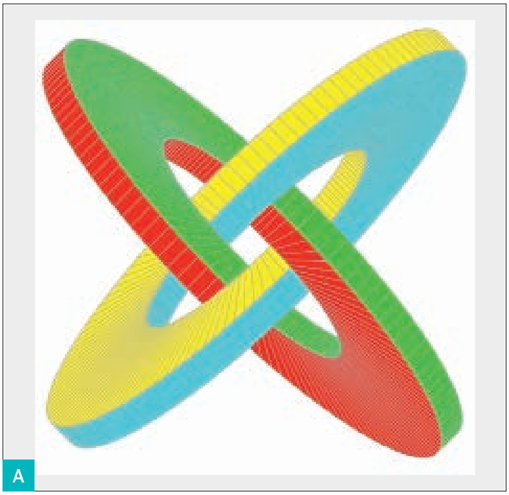
Try putting 3 genuine hen's eggs inside a wooden box and closing the lid. When you reopen it, you find 4 hen's eggs, which, when broken, are found to be perfectly genuine. No gimmicks in the box, no sleight of hand. Good trick if you could do it, but nature doesn't work that way.

Apparent Impossibilities

Ever since craftsmen made wooden models of sailing ships inside glass bottles, people have delighted in making "seemingly impossible" artifacts. The peach inside a glass bottle of peach brandy is one example. The neck of the bottle is far too small for a peach, but just right for the branch and pollinated blossom of a peach tree. Time in the summer sunshine does the rest.

You can buy bottles with small necks with a complete pack of playing cards inside, still sealed with the tax label. The mystery of how it's done would be answered by watching someone painstakingly make one, but then the finished object would seem less fascinating.

The difficult we do right away. The impossible takes somewhat longer.
—Engineer's joke



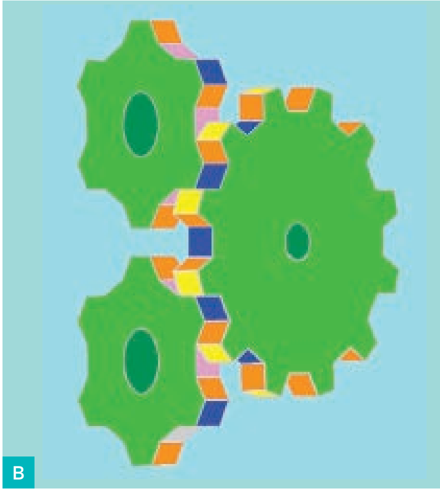


Fig. A: Through the illusion of color and depth ambiguity, these washers appear impossibly linked.

Fig. B: Inspired by the frictionless world of quantum mechanics, the colored gear teeth make it easier to pick out the illusion.

Donald Simanek

And of course there are the tiny bottles with a genuine coin inside, the bottle having been blown around the coin. Search "impossible bottle" on Wikipedia.

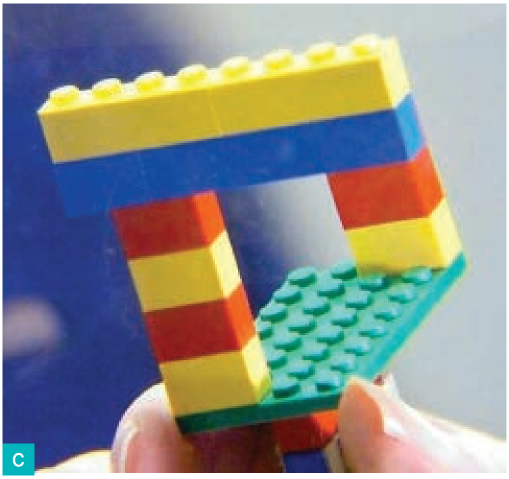
Visual illusions are usually 2-dimensional, artistic depictions of things not possible in 3-dimensional space. Figure A is one of mine. At casual glance it seems to depict 2 flat washers interlocked, but then you notice that the interlocking would be impossible if the washers were really flat. And even worse, each washer is self-contradictory in its depiction, taking advantage of the depth ambiguity of the near and far edges of ellipses. The colored faces and edges give the game away — the front faces seem to connect with back edges of each washer.

Many illusion pictures, rendered on a flat surface, succeed by such artistic ambiguities of perspective. The illusion would be destroyed if depicted from a different angle. Some clever artists make sculptures that appear to be entirely different things when seen from different angles, and the next step is sculptures that appear to be different illusions when seen from different angles.

Gears are useful for those who make machinery, but pesky friction is ever-present. This inspired me to design the 3-gear system in Figure B. As the gears mesh, gear teeth are transformed to an indeterminate quantum state where they are neither here nor there, and it's impossible to determine which gear they belong to. It's well known that there's no friction in quantum mechanics, so these gears must be perfectly efficient. At least that's my theory. I've colored the faces of the teeth to make it easier for you to understand the principle. I hoped someone more skilled than I might produce an animated version showing the gears rotating and the gear teeth morphing where they mesh. It's a challenge!

Often the geometric peculiarities of isometric perspective are the trick that makes these illusion pictures perplexing. Isometric perspective removes the vanishing points of photographic perspective, so that parallel lines remain parallel and don't converge in the picture. Engineering drawings use this technique so there's no size reduction with distance and all dimensions may be measured with a ruler on a flat page.

So, could such an illusion be photographed? My experimental shot of an impossible triangle



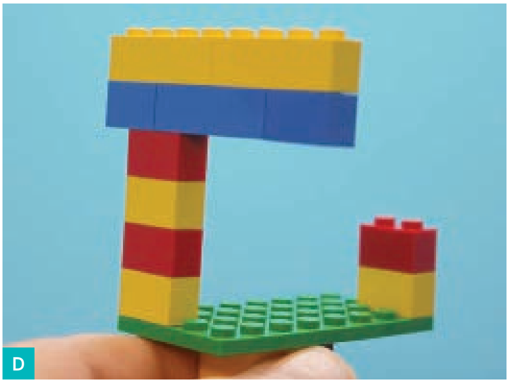


Fig. C: A Lego impossible triangle illusion, shot using lenses arranged in a telecentric system: a 6"-diameter magnifying lens with an inexpensive digital camera at its focal point.

Fig. D: The illusion revealed.

Figs. E and F: Gregory Hayes, photo editor at MAKE, was bitten by the challenge to make a Lego illusion photo without digital manipulations. He didn't use a telecentric system or alter the parts. So how did he do it? Find out at makeprojects.com/v/30

made from Legos (shown in Figure C) was achieved with a digital camera and some simple lenses arranged in a telecentric system, which renders reality in isometric perspective.

Notice how the far edge of the green base plate seems larger than the near edge. Yet careful measurement of the picture, using a ruler, shows that it isn't. If this were classical photographic perspective, the far edge would be shorter in the picture.

You can take such pictures yourself. To learn

more, see my article on telecentric lens systems at makezine.com/go/telecentric.

Can such pictures work in stereo 3D photography? I've not done it yet, but it may be possible using some other deceptions. Can ordinary artistic illusions be rendered in 3D? Some can. For examples see makezine.com/go/3dphoto.

We mustn't forget that these are only lines and color on a flat page. It's our brains that, from long experience, condition us to interpret them as if they were familiar objects like washers, gears, and rectangular blocks.

We can imagine many things that nature doesn't allow us to make; we just don't always know in advance what they are. But sometimes nature has already told us all we need to conclude that they're impossible, and pursuing them would be futile. Some things can be faked with deceptive illusions. And some things, like a 3-headed flat coin, will take considerably longer to achieve. Like forever.

I challenge you to try your hand at these impossibilities and take them a step further. If you do, email me your ideas and responses (dsimanek@lhup.edu), and I'll add them to my website.

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.

Gregory Hayes (E and F)

DANGER!

By Gever Tulley with Julie Spiegler

MELT GLASS

Harness the superheat of fire.

Firewood typically burns at around 900°F but bottle glass doesn't melt until almost 1,400°F, so we must force the fire to burn hotter by feeding it extra oxygen and constraining the heat to a small area.

1. Prepare your fire area. It must be clear of all combustible material so that you can let your fire burn itself out naturally.

2. Build an oven. Place 2 large logs side by side with a gap between them just large enough to lay the bottle in. Align the logs so that the wind blows straight through the gap. This is going to be the combustion zone.

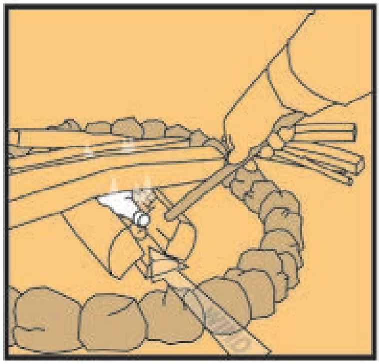
3. Ignite. The upwind side of the gap is the front of your fire; the downwind side will be the exhaust. Place paper and kindling in the front third of the gap and get your fire started.

4. Build up the fire. Once the kindling is really starting to burn, blow gently on it. Feed kindling and larger pieces into the fire until the logs on either side are burning on their own.

5. Add the bottle. Put on goggles and use a stick to place a bottle at the hottest part of the fire. Place some small firewood across the top of the combustion area to seal in the heat, but make sure the upwind end remains open.

6. Increase the heat. Blow gently and feed medium-sized sticks into the combustion area to keep it well fed until the bottle slumps. Slumping happens when the glass becomes so soft that it cannot hold its shape.

Gever Tulley



WARNING: Glass that is heated to the melting point and then cooled quickly can shatter explosively. Make your fire somewhere that you can let it burn itself out rather than dousing it with water.

REQUIRES
Fire
Water bucket
Glass bottle, soda- or pill-sized
Safety goggles
Adult supervision

DURATION
2–3 Hours

DIFFICULTY
Difficult

SUPPLEMENTARY DATA

A bellows is designed to draw air into a chamber and then force it out through a small opening pointed at the combustion zone. The extra air makes the fire burn faster and hotter. This is useful for melting glass or metal.

Natural glass is made in volcanoes, and by lightning strikes and meteor impacts. Crude forms of glass can be made by heating sand mixed with the ash created by burning certain kinds of plants. So a fire made on a beach might create a small amount of glass, given the right conditions — which is how many archaeologists think the process was first discovered.

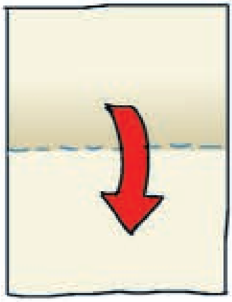
7. Cool down. Allow the fire to burn itself out slowly to prevent the glass from shattering due to sudden temperature changes. Once the fire is cool to the touch, use a stick to gently lift the melted bottle from the ashes. It may be very fragile, so be careful when handling it.

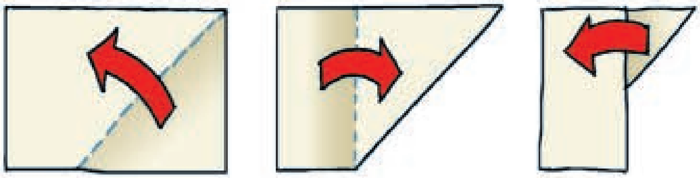
Excerpted from *Fifty Dangerous Things (You Should Let Your Children Do)* by Gever Tulley with Julie Spiegler (fiftydangerousthings.com). Gever is co-founder of Brightworks, a new K–12 school in San Francisco (sfbrightworks.org).

HOWTOONS.COM

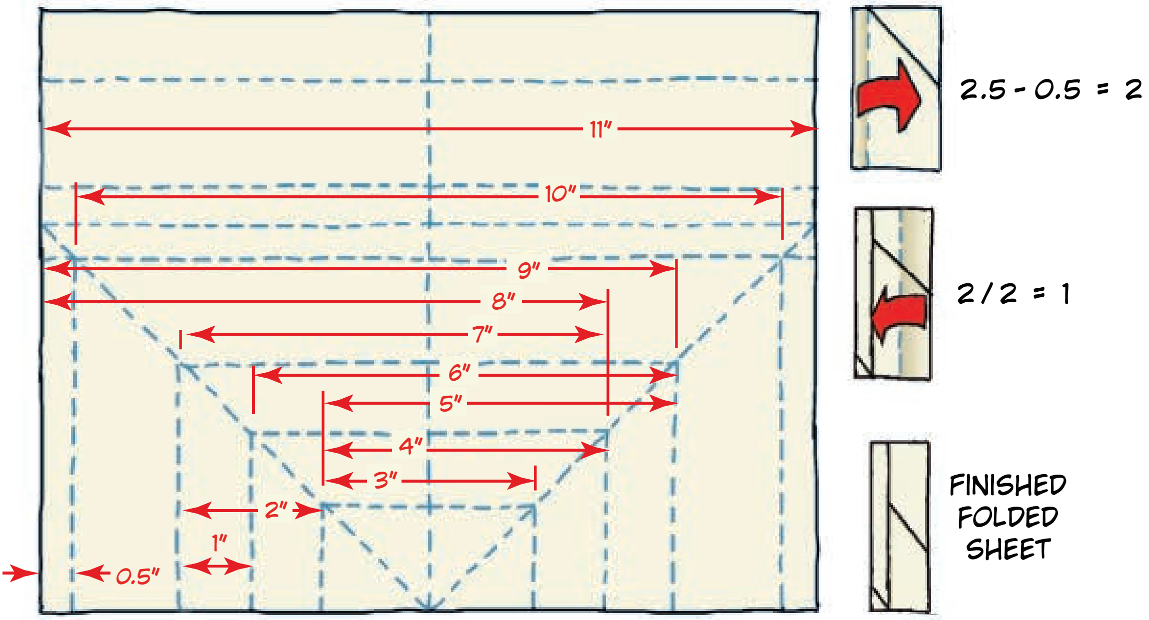
THE MEASURE OF A MAN

USING THESE **6 GEOMETRIC FOLDS**, WE CAN MAKE THIS SHEET **MEASURE** ANYTHING IN ***INCHES***.



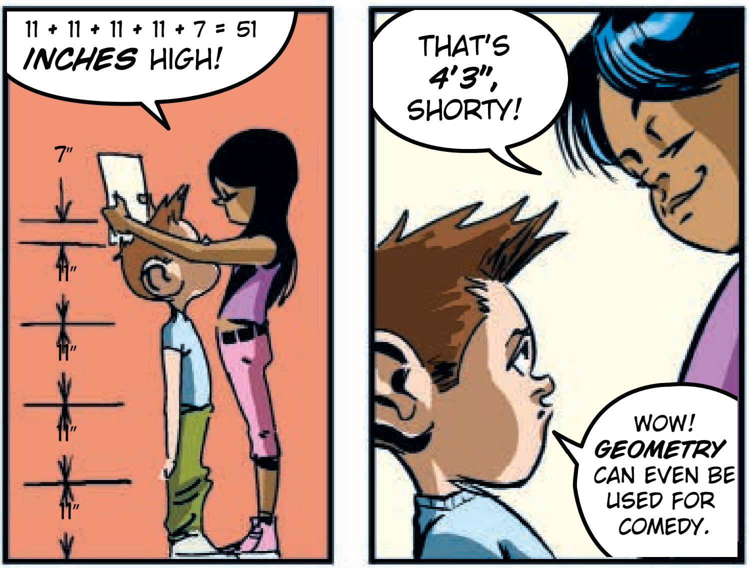


11 / 2 = 5.5 | 8.5 - 5.5 = 3 | 5.5 - 3 = 2.5 | 3 - 2.5 = 0.5



"GEOMETRY ENLIGHTENS THE INTELLECT AND SETS ONE'S MIND RIGHT. ALL ITS PROOFS ARE VERY CLEAR AND ORDERLY. IT IS HARDLY POSSIBLE FOR ERRORS TO ENTER INTO GEOMETRICAL REASONING, BECAUSE IT IS WELL ARRANGED AND ORDERLY. THUS, THE MIND THAT CONSTANTLY APPLIES ITSELF TO GEOMETRY IS NOT LIKELY TO FALL INTO ERROR."

-IBN KHALDUN, 1332-1406



ELECTRONICS: FUN AND FUNDAMENTALS
By Charles Platt,
Author of *Make: Electronics*

MAGIC 8 BOX

Use rotary encoders to make a digital fortune teller.

Everyone wonders about the future — which may explain why a fortune-telling toy called the Magic 8 Ball has been a popular novelty item for more than 50 years. Shake the ball, ask a question, turn it over, and words of advice appear beneath a plastic window (Figures A and B). The lettering is actually embossed on the 20 triangular faces of an icosahedron, floating in blue dye. Figure C reveals the secret.

I wanted to make an electronic version, although I quickly decided to settle for a Magic 8 Box, since a ball would be too difficult to build. To generate the fortunes randomly, several possibilities came to mind:

Option 1: Use a microcontroller to display a message on an alphanumeric screen. But that seemed too soulless and boring. I wanted to preserve some of the low-tech attributes of the original toy. I wanted to pick it up and shake it to activate a random message.

Option 2: Use an accelerometer? I applied the attributes of this component to a "Do-Not-Touch Box" in MAKE Volume 27. It creates random varying resistances, which I could convert from analog to digital, but I didn't see how to ensure that each result would be equally probable.

Option 3: Use a shock/vibration sensor? Pulses from a sensor such as the D7E series from Omron could step through a series of LEDs, but if someone shook it only a few times, the outcome wouldn't be very random.

Option 4: How about a rotary encoder? I imagined a way to make this work. It would be funky and eccentric, but fun. Since I'd been looking for an excuse to play with encoders anyway, that settled it. (Incidentally, if you go browsing through parts catalogs, be careful to distinguish between optical encoders, which are the kind you have in your computer mouse, and mechanical encoders, which are the ones I'm using here.)

→ START

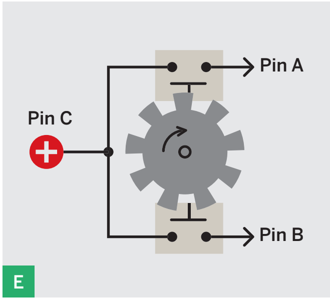
Encoders Are Everywhere

When you adjust the volume on a modern stereo or rotate a dial on a digital camera, you're probably using a rotary encoder, aka rotational encoder. Examples are shown in Figure D. Inside each is a pair of switches that open and close as the shaft rotates. If you turn it clockwise, switch A closes slightly before switch B. If you turn it counterclockwise, switch B closes before switch A. The switches are powered through a common terminal C, usually the center terminal.

You can imagine an encoder containing a toothed wheel that pushes first one switch, then the other, as shown in Figure E. Really it's not quite like this, but the diagram is a useful visualization tool. Assuming the wheel turns clockwise and pin C is positive, the outputs from A and B will run through 4 possible on-off combinations, shown in Figure F.

Figure G (page 161) shows the same thing graphically, with detents included as dotted lines. Detents are the little clicks you can feel when you turn the shaft of a decoder. Actually some decoders have no detents at all; they just turn smoothly. Others have 1, 2, or 4 detents for each pulse, which corresponds to each tooth in Figure E. I chose 4 detents per pulse (DPP), because I wanted a unique combination of pin states for each "click" of the encoder, to make each combination equally probable.

Unfortunately, most encoders don't have 4 DPP. The only one I found cost 5 times as much as a cheapie with no detents at all. Both are included in the Materials list; take your pick. On the more expensive one, the center pin is common; on the cheaper one, it's the pin on the right when all pins are facing you.



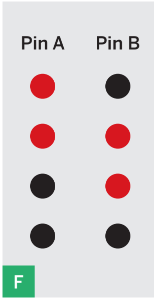


Fig. A: The original Magic 8 Ball, so famous it even has a Wikipedia entry.

Fig. B: The Magic 8 Ball reveals a fortune.

Fig. C: How the Magic 8 Ball stores its fortunes.

Fig. D: A selection of rotary encoders.

Fig. E: An imaginary view suggesting how an encoder works.

Fig. F: Switch outputs (red=closed, black=open) from pins A and B of an encoder as the shaft rotates.

MATERIALS AND TOOLS

Rotary encoders, mechanical, incremental (2) Bourns ECW0D-C24-BD0009 (about $8.50 each) or Bourns PEC16-2015F-N0024 (about $1.20 each). The more expensive part is more robust and may give a more evenly random output. Your choice.

Decoder IC, 74HC4514 type This part number may be preceded by other letters, which are unimportant.

Voltage regulator IC, LM7805 type

LEDs, 5mm, through-hole, with diffuser lens (17) with maximum steady forward current 30mA at 2V DC, such as Lumex SSL-LX5093ID-TR20

Resistors, 1/4W minimum: 10kΩ (5), 120Ω (2)

Switch, micro lever, SPDT such as Honeywell ZM50E10E01 or any other SPDT snap-action limit switch requiring no more than 50 grams to activate it

Sinker weights, egg-shaped, approx. 1oz (2) from a fishing tackle supplier or big box store

Wire, galvanized steel, 14 gauge, 1' length from a hardware store

Transparent film for overhead slide projectors, 6"×6" or very thin paper

Plastic sheet, transparent, red, 6"×6" from a file folder or any other source

Battery snap connector, 9V

Battery, 9V

Hookup wire

Epoxy glue

ABS plastic, or 1/4" plywood, or 1/8" masonite for an enclosure

Soldering iron and solder

Cutting and construction tools depending on your method of manufacture

Charles Platt

To utilize the encoder, I drilled a small hole through its shaft, inserted 2" of #14 galvanized wire, hung a weight on the end, and used epoxy to hold everything together, as shown in Figure H. The weight was an egg-shaped lead sinker made for fishing. It would act like a pendulum, swinging randomly if someone shook or turned the box containing the encoder. This was my source of random pulses.

Now, how could I use merely 4 output combinations to generate multiple fortunes? Well, if I added a second encoder, their combined outputs would give me 4 × 4 = 16 combinations, each of which could light a single LED, which would display a message. Not as many as in a Magic 8 Ball, but good enough.

A Decoder for My Encoder

To convert the encoder outputs, I could feed them into a chip known, appropriately, as a decoder. (I used one of these in the downloadable version of the schematic for "Extreme Zap-a-Mole" in MAKE Volume 24.) This chip interprets 4 high/low inputs as a 4-bit binary number, turns it into a hexadecimal number, and powers one of its 16 output pins, each of which can supply 25mA — just enough to drive an LED directly.

Designing the schematic was now very easy. Just connect the 4 outputs from 2 rotary encoders to the 4 inputs of a decoder. Connect the 16 outputs from the decoder to 16 LEDs. Job done!

Actually it was a little more complicated, because I had to use pull-up and pull-down resistors to stop the encoder input pins from "floating" whenever a switch connected to them was open. And I added a couple of tricks to make the Magic 8 Box behave nicely. If you build this project, it functions like this: pick it up, switch it on, shake it, put it down, and a fortune lights up. A snap-action switch (sometimes known as a micro switch or limit switch) sticks out underneath the box, so that the switch closes when the box is placed on a flat surface, activating the display and also latching the decoder to hold the selected fortune for inspection.

The schematic is in Figure I. Switch S1 is an on-off power switch with D1, an LED just to remind you that the toy is switched on. S2 is the normally open snap-action switch mounted on the underside of the box. S3 and S4 are the rotary encoders, each with its power input (terminal C) at the center, and terminals A and B at either side — which is how the actual component is usually configured, but look up the datasheet for the rotary encoder you use, just to make sure. R1 through R5 are pull-up and pull-down resistors. Each of the 16 LEDs lights up a fortune, and because only one LED is active at a time, they can share one series resistor (R7).

The 5V DC power supply is not shown, but a 9V battery connected through an LM7805 voltage regulator would be appropriate.

Building the Magic 8 Box

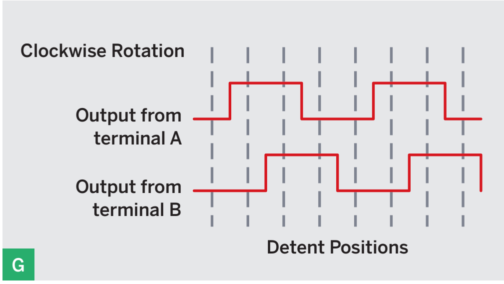
I mounted each encoder on a small square of plastic, one above the other, and put them inside a box measuring about 5" on each side.

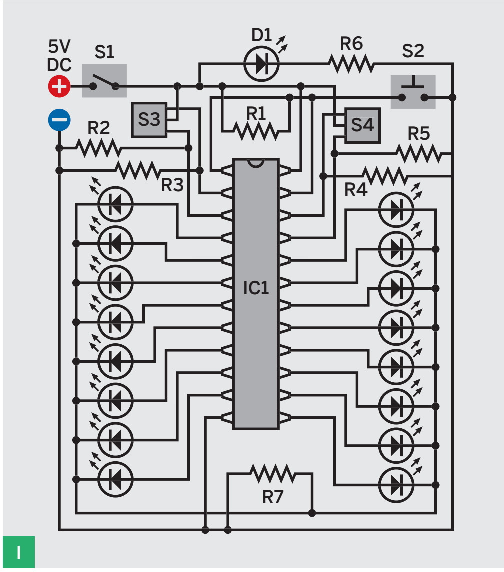
To display the messages, I put each LED in its own little cell formed by chopping a ¾" square plastic tube into 16 sections. I glued them together, as shown in Figure J. (You could make them from cardboard, and the result would be almost as good). I laser-printed my fortunes onto clear plastic film, which is sold in stationery stores for overhead projectors, but you could print them onto thin paper instead.

To conceal the fortunes that are not illuminated, I added a couple of thicknesses of transparent red plastic that I snipped from a file folder. My Magic 8 Box was built from plastic (Figure K), but you could use thin plywood or masonite.

As for the fortunes, Figure L shows the ones that have been found inside a Magic 8 Ball for the past five decades. I decided they were due for a makeover, so I wrote my own. You can do the same, but just remember, when you predict the future, people usually prefer to receive good news rather than bad news!

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.





MAGIC 8 BALL FORTUNES

1. POSITIVE
It is certain
It is decidedly so
Without a doubt
Yes — definitely
You may rely on it
As I see it, yes
Most likely
Outlook good
Signs point to yes
Yes

2. UNCERTAIN
Reply hazy, try again
Ask again later
Better not tell you now
Cannot predict now
Concentrate and ask again

3. NEGATIVE
Don't count on it
My reply is no
My sources say no
Outlook not so good
Very doubtful

L

Fig. G: Graphical depiction of outputs from a rotary encoder that has 4 detents per pulse.

Fig. H: A weighted arm can act as a pendulum on an encoder when it is shaken or turned.

Fig. I: Magic 8 Box schematic. S1: Any miniature on-off switch. S2: Snap-action or limit switch protruding beneath the box. R1 through R5: 10K. R6 and R7: 120 , ¼W minimum. See materials list for other details.

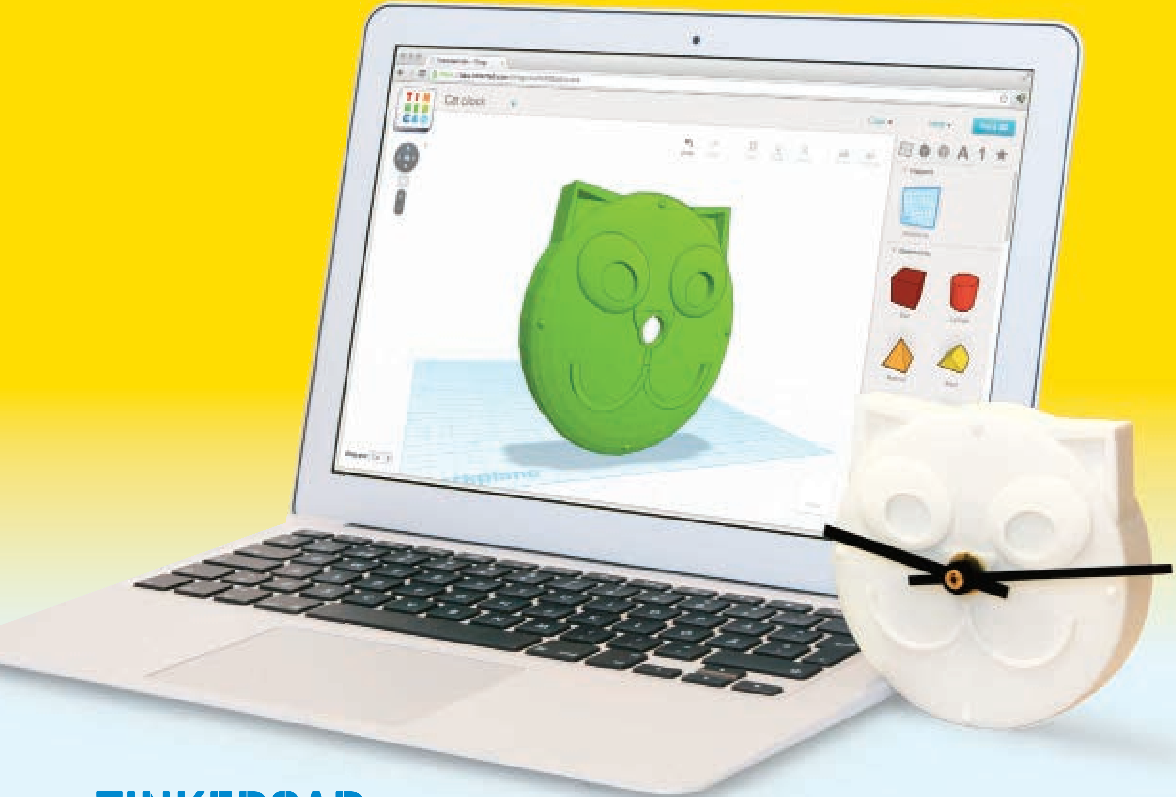
Fig. J: Each LED is mounted in a separate cell to contain its light output.

Fig. K: The completed Magic 8 Box.

Fig. L: The traditional list of fortunes in a Magic 8 Ball.

Paint your couch, get hypnotized, consolidate your remotes, control your robot army, and design in 3D for free.

TOOLBOX



TINKERCAD 3D MODELING SOFTWARE

Free tinkercad.com

Based out of Finland, Tinkercad Inc. has developed software to easily bring 3D printing and design to the masses through a fun and intuitive user interface that runs inside your web browser. After raising $1 million in seed funding in November 2011, they launched the latest version of Tinkercad software. Go to tinkercad.com, and you can design a new part, follow a "Quest" tutorial to hone your 3D modeling skills, or copy and edit parts that someone else has already designed and shared. When you're done, Tinkercad can export your part as an STL file so you can easily print it on a 3D printer. But don't worry — if you don't have a 3D printer on hand, you can have instant access to 3D printing services via Shapeways, Ponoko, and i.materialise, who will take the files and print your parts (for a small fee). Follow the Tinkercad blog to see all the cool stuff they're making, and watch the tutorial video to get started.

—Nick Raymond

HypnoCube 4Cube USB Kit

$150 hypnocube.com

The HypnoCube is one of the most visually pleasing kits available — 64 RGB LEDs pulsating in sync are mesmerizing! Unfortunately, it's also one of the harder kits to assemble, as each of the LED leads must be bent accurately and soldered onto galvanized steel wire. The control board is easy enough to put together, but the bulk of the work, the light-up lattice, is a painstaking and potentially frustrating process. Don't be discouraged, though; the finished product amazes all who see it! If the preloaded designs aren't enough, you can design unique patterns and transfer them from a computer to the cube.

—Paul Mundell

Dremel Multi-Max MM40

$130 dremel.com

What looked to be a messy task — cutting out a hole in drywall — became much easier when the Dremel Multi-Max MM40 came in. The tool cut through ⅝" drywall with ease, and can definitely handle a greater thickness of any wood. Next, we used the included rigid scraper blade to clear away the glue left from a removed carpet, a task it handled with ease. Its blade-changing system falls short of perfection, however; as is the case with oscillating tools, heavy duty work vibrates the blade and loosens the attachment. Overall, the Multi-Max can handle most fixes and cuts, with only minor inconvenience from the vibrations.

—PM

STANLEY 19" TOOLBOX

$18 stanleytools.com

Most inexpensive toolboxes have two metal latches that are slow to open and close. Stanley's 19" toolbox one-ups such models, literally. It features a one-touch latch that can be lifted with a single finger, allowing for quick and easy opening and closing. I find the 19" model perfect for small or specialized tool kits, but 16" and 24" sizes are also available. A removable tray and two small parts compartments add to its appeal.

—Stuart Deutsch

TOOLBOX

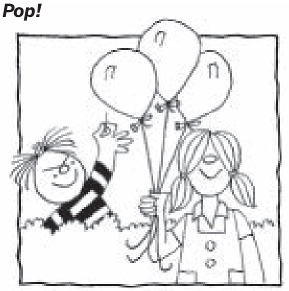
EL WIRE STARTER PACK

$20 **makershed.com**

Want to add the cool (literally) glow of EL wire to your projects but not sure where to start? This nifty little pack does all the work for you and comes soldered and ready to go. Pop in two AA batteries, revel in the light of the 8-foot strip of aqua blue EL, and *Tron* up some accessories. Features blinky and solid modes accessible with the push of a button. Copper tape and heat shrink are included if you want to try soldering the EL yourself, and Adafruit's clear instructions make it a snap.

—Goli Mohammadi

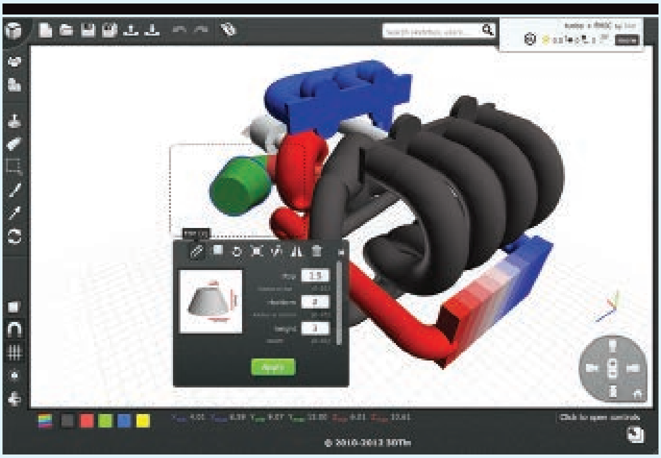
Eureka! By Roy Doty
Pop!



Petzl Pixa 1 LED Headlamp

$37 **petzl.com**

Petzl's pro-grade Pixa 1 may be a bit large and over-featured for my modest needs, but it's also one of the finest LED headlamps I have ever used. It throws a wide and gently bright beam that is perfect for close-up work, such as soldering or tinkering inside a computer case. *—SD*



3DTin Free **3dtin.com**

Developed in India by software engineer Jayesh Salvi, the 3DTin modeling program runs inside Google Chrome or Firefox with WebGL support. Get started building parts, simple and complex, using a library of predefined shapes. Control the size, rotation, color, and grouping of objects to create files that can be shared online or exported for 3D printing.

The software is free as long as you agree to share all your sketches under Creative Commons licensing, otherwise you can opt for the $5 Premium version and reserve all rights. Export files as PNG, OBJ, DAE, or STL formats using the downloads feature in your web browser, or publish your files right to Thingiverse and the 3DTin library to share with the community. Users also have the option of sending their files to i.materialise, who will print the parts in full color using their awesome 3D printing lab, for a fee. Salvi is constantly working to improve 3DTin and add new features, so get building. *—NR*

Vectric VCarve Pro 6.5

$599 vectric.com

After I built my CNC machine, I used some free tools to turn CAD drawings into G-code, but I soon found myself wanting more control, capability, and simplicity. I researched my options and found the Vectric VCarve Pro, which does nearly everything you want and more. You don't need a separate CAD or vector graphics program to use it, as everything you need to lay out, create, and edit vector art is built-in. There's also a very helpful "fit vectors to bitmap" function.

A professional software package, it's designed with a number of automated features to save you time and money. These include "nesting," which finds the optimal arrangement to squeeze parts into the material to reduce waste, and automatic "tab placement," which makes it easy to add small tabs to keep your creations from slipping as your router cuts them out. Another great pro feature is the "estimated machining time" function.

VCarve Pro has allowed me to streamline my workflow and has greatly increased what I can do with my CNC router. I've found it amazingly easy to use, and what I can't figure out is clearly explained in the video tutorials on Vectric's website. Also, Vectric's customer support is second to none, so it's good to know that help is there in case you need it.

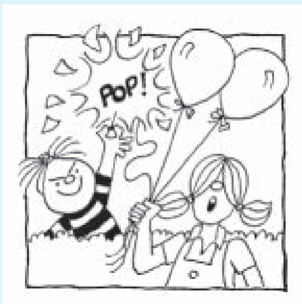
—Michael Castor

VOOMOTE ZAPPER

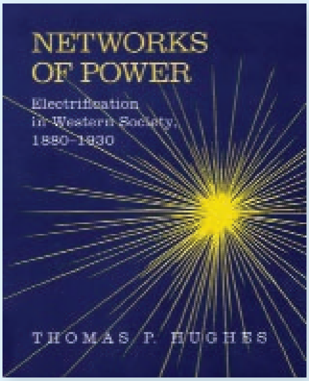
$70 voomote.tv

This gadget turns your iPhone, iPod touch, or iPad into a universal remote control. The free app is slick and powerful: it learns your devices, displays a clone of each remote, and organizes them by room. You can move buttons, assign functions, write "one-touch" sequences for multiple devices, and mash up remotes (like, put the TV volume on the DVD remote, nice!). The app revived our DVD player's lost functions, with a better interface than our old Harmony universal remote. Quibble: some older devices aren't in the code library (though you'll find something that works).

—Keith Hammond



MAKE LOOKS AT BOOKS

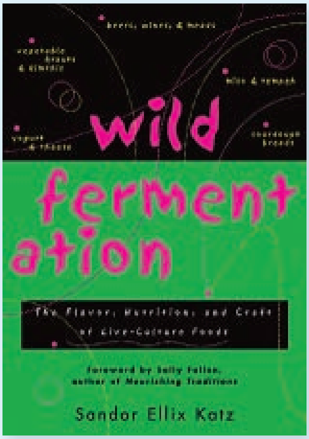


Knowledge Is Power

Networks of Power: Electrification in Western Society, 1880–1930
by Thomas P. Hughes $47 Johns Hopkins University Press

If you've ever wondered what went into making the foundations of the power grid that we know today, here's a good place to start! From city planning and patents to the technology and the social factors that shaped its integration, this book leaves nothing out. Hughes is technically and historically rigorous in his research, but he also effectively conveys the drama of it all — the charge of many brilliant inventors collaborating to devise a universal electrical system yet often striving to populate it with their own inventions. *Networks of Power* is truly a riveting account of one of the most definitive eras of technological development in modern society.

—Meara O'Reilly

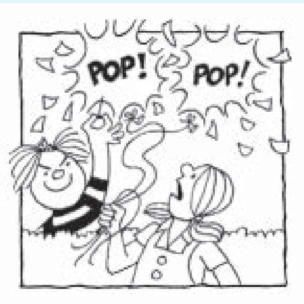


Get Cultured

Wild Fermentation **by Sandor Ellix Katz $25 Chelsea Green**

When was the last time you ate something fermented? Despite a modern fixation on pasteurization and sanitation, the process of allowing food to "spoil" in a controlled environment is still more ubiquitous than some would think. As author Sandor Ellix Katz points out, "Fermentation gives us many of our most basic staples, such as bread and cheese, and our most pleasurable treats, including chocolate, coffee, wine, and beer." Aged traditions, easy, enticing recipes, and extensive instructions on how to make everything from sauerkraut to homebrew ginger beer make this the go-to manual for all things cultured.

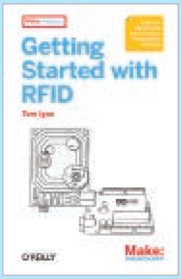
—MOR



New from MAKE and O'Reilly

Getting Started with RFID **by Tom Igoe**
$6 O'Reilly Media

Build simple, extensible, and customizable projects based on radio frequency identification (RFID) for short-range identification of physical objects. Based on the projects from the first edition of *Making Things Talk*, this book shows you how to create projects with Arduino, Processing, and the Getting Started with RFID Kit from Maker Shed.



Raring to Repair

***The Art of Fixing Things* by Lawrence Pierce $13 CreateSpace**

This is a rare beginners' how-to book that doesn't treat you as a dummy, but rather as someone who just hasn't had the chance to build a lifetime of basic tool knowledge. It starts out explaining which tools you ought to have and how to use them, and moves on to fixing specific things (changing your car's oil, repairing a garden hose) and general things (making your own tool to repair damaged threads, making a neat punched hole). The author is the lovably grouchy, incredibly skilled uncle you wish you had, full of wry advice passed down from past generations. Most importantly, you'll learn that "when something breaks, you risk nothing by taking it apart to see if it can be fixed."

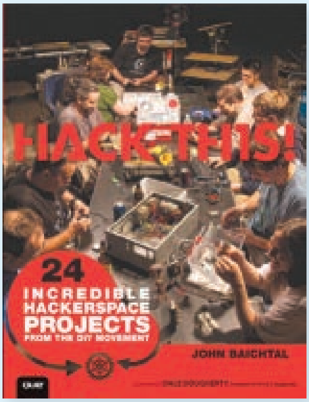
—Arwen O'Reilly Griffith

Open Spaces

***Hack This!* by John Baichtal $30 Que**

Hackerspaces are people! MAKE contributor John Baichtal understands this and does a fine job of covering the 24 featured spaces. You get a profile, details of the space, photos, and other fun, useful tidbits. But hackerspaces are projects, too! Baichtal describes a project (or two) from each hackerspace, who worked on it, and what the outcome was. There are 24 main projects in all, from a sandwich-making robot to a blast furnace, with brief build details and links to more info online. The book also describes the key tools used in hackerspaces, and offers supportive info like glossaries and etymologies. There's even a sort of hackerspace playbook in the back, covering the basics of what you need to know to start your own hacker/makerspace.

—Gareth Branwyn



Environmental Monitoring with Arduino by Emily Gertz and Patrick DiJusto

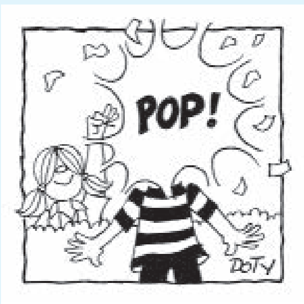
$8 O'Reilly Media

Build simple, usable devices to gather data about different conditions in the environment by using Arduino and basic electronics. Each chapter briefly explains a particular environmental problem and features step-by-step instructions to build the appropriate monitoring device.

Craftsman G2 Nextec 12V Multi-Tool

$100 craftsman.com

While I usually prefer corded oscillating tools, it's hard not to like Craftsman's second generation 12V multi-tool. Not only is it lightweight and comfortable to use, it boasts a tool-free blade change for less hassle. I feel that a bit of speed and power was traded for greater battery life, but that's a plus in my book. The kit includes a fair number of accessories, but you may want to pick up a Dremel or Bosch adapter to take advantage of those brands' more extensive selections. *—SD*



ShopBoss

$30 fiskars.com

The heart of these snips is a pair of titanium nitride-coated snippers/shears, with a serrated bottom blade. They're made to cut through light metals, carpet, cardboard, plastic stock, etc., and they made easy work of most everything I chewed into, even some fairly thick acrylic. They cut CD media easily and cleanly and would be a good tool to grab when building CoasterBots. It was a joy to process a giant pile of boxes, plastic banding, and cardboard destined for the recycling center.

Surrounding the snips are a number of other useful widgets: a wire-cutting jaw, twine/binding strap cutter, bottle opener, and pegboard hanging loop. They even come with a plastic holster that clips onto your belt, but it feels a little off.

—GB

Couch Spray Paint. No, Seriously.

$20 simplyspray.com

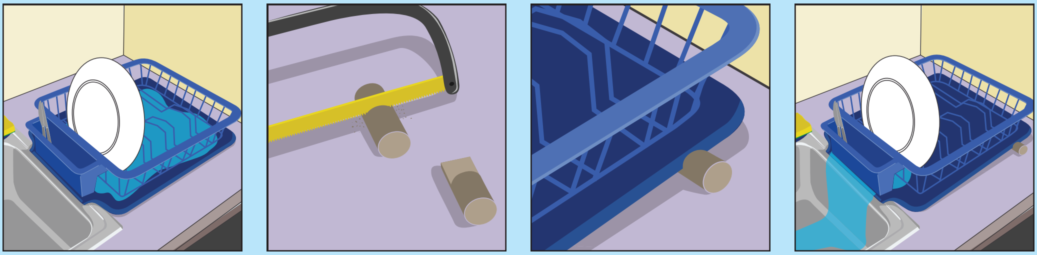
Considering what a ridiculous idea upholstery spray paint is, this stuff works almost astoundingly well. The starting color of your furniture makes a difference. Over the dead-grass yellow of my secondhand armchairs, orange went on extremely well. Periwinkle blue didn't cover so well.

When dry, the color is waterproof, odorless, and doesn't rub off or transfer under any conditions that I've discovered. Both chairs were a bit crunchy right after application, but the crunch soon wears off without otherwise affecting the color. While I can't say I'd unequivocally recommend this product to everyone, it does work a heckuva lot better than I ever imagined, and it was a lot of fun to use.

—Sean Michael Ragan

Tricks of the Trade By Tim Lillis

Put a cork on it.



Does your dish rack drain poorly, collecting water that sits around until you remember to clean it out? Thanks to this trick from Zach Watson, you will no longer have this problem.

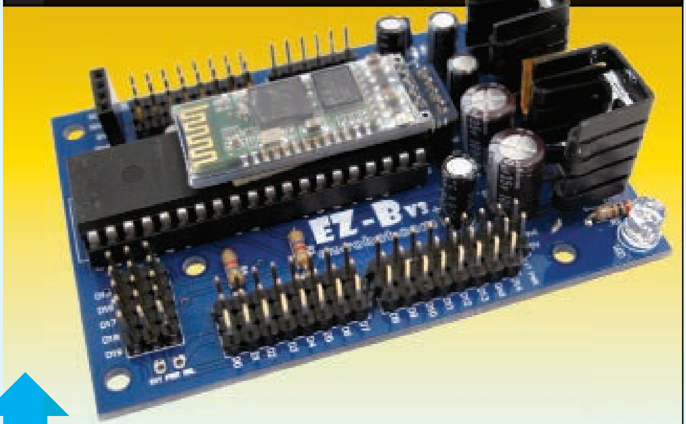
All you need are some wine corks (or similar material) and something to cut them with. Notch the corks so the rack will nest inside. Place them at the two corners opposite the draining end.

All dish racks are different, so cut the corks in a way that enables the perfect nesting of your dish rack. You may need to try out various heights.

Voilà! With just that small lift at one end, your dish-water will henceforth drain away into the sink and keep the rack dry.

Have a trick of the trade? Send it to tricks@makezine.com.

EZ-Robot Controller



$99 **makershed.com**

When I first got to play with the EZ-Robot Controller, I assumed I would have to learn its programming syntax and the on-board Bluetooth would be hard to set up. I was wonderfully wrong. Once I paired the device to my computer and fired up the EZ-Builder software, I was greeted by a friendly drag-and-drop environment. I hooked the EZ-Robot Controller up to a Boe-Bot chassis and proceeded to play around. In under five minutes I had my crude-looking robot chasing my dog around using voice commands!

I'm blown away by the simplicity of the system and how even complicated things like object tracking and face detection (bring your own camera and servos) are built into the software. If you're the least bit interested in building robots and hacking toys, I urge you to check this thing out. You won't be disappointed! *—MC*

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

Michael Castor is the evangelist for the Maker Shed (makershed.com).

Stuart Deutsch is a DIYer, and writes a whole lot more about tools at toolguyd.com.

Keith Hammond is projects editor at MAKE.

Tim Lillis is a freelance illustrator and DIYer (narwhalcreative.com).

Paul Mundell is one of MAKE's awesome engineering interns.

Meara O'Reilly (mearaoreilly.com) is a sound designer.

Arwen O'Reilly Griffith is staff editor at MAKE.

John Edgar Park is a frequent contributor to makezine.com.

Sean Michael Ragan comes from a long line of makers, and blogs at makezine.com.

Nick Raymond is intern coordinator of MAKE Labs.

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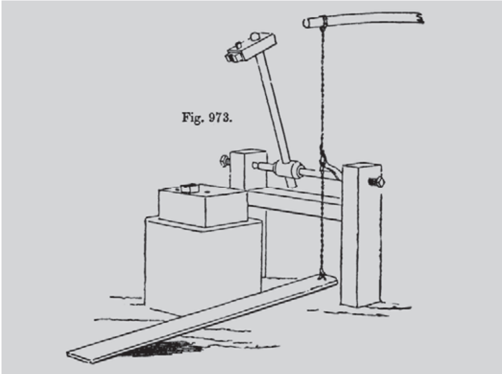
Have a tool worth keeping in your toolbox? Let us know at toolbox@makezine.com.

REMAKING HISTORY
By William Gurstelle, Workshop Warrior

THE OLIVER: A LEG-POWERED HAMMER

Build the treadle hammer that helped build medieval Europe.



A medieval-style foot-operated Oliver hammer, from *The Practical Metal Worker's Assistant* by Oliver Byrne (no relation to the hammer), 1864.

If you examine the nails holding medieval European buildings together, you'll find they're different from the nails available today. They're better. Today, nails are machine-sliced from a strand of hardened wire and the cross section is round; when you pound one into wood, you force it between the individual fibers. Such nails work adequately in softwoods like pine, but often split hardwoods like maple or walnut.

The medieval iron nail is an entirely different animal. Each nail was wrought, that is, beaten into shape by hammer blows. The cross section of a wrought iron nail is rectangular, with a hand-filed chisel point that doesn't simply push wood fibers aside; it actually cuts through them. Wrought nails can even be driven into oak without splitting it, and once in, they're nearly impossible to remove.

Of course, wrought nails, like just about everything else a blacksmith made, required a lot of muscle. To make a nail, the smithy heated a bar of iron to red-hot in his forge. Then he hammered the bar until it formed a point. Then he reheated the nail and, using a special tool, upset the other end with an even bigger hammer to form the nail head.

This technique was invented by the Romans and continued until a nameless but clever 14th-century blacksmith in the north of England came up with a way to substitute the large muscles in his legs for the relatively puny muscles in his arms. This invention, the Oliver, revolutionized ironworking in Europe. It's a small lift-hammer that uses a sapling (the holly tree was preferred by English smiths) as a tension spring to raise a hammer that pivots on an axle. The hammer is then pulled down by a foot-operated treadle to strike.

In the 18th century, water- and steam-powered hammers made the tree-branch "spring pole" obsolete. But for about 500 years the Oliver was one of the most important machines in the world and allowed nails and other precious bits of ironwork to be made faster and less expensively.

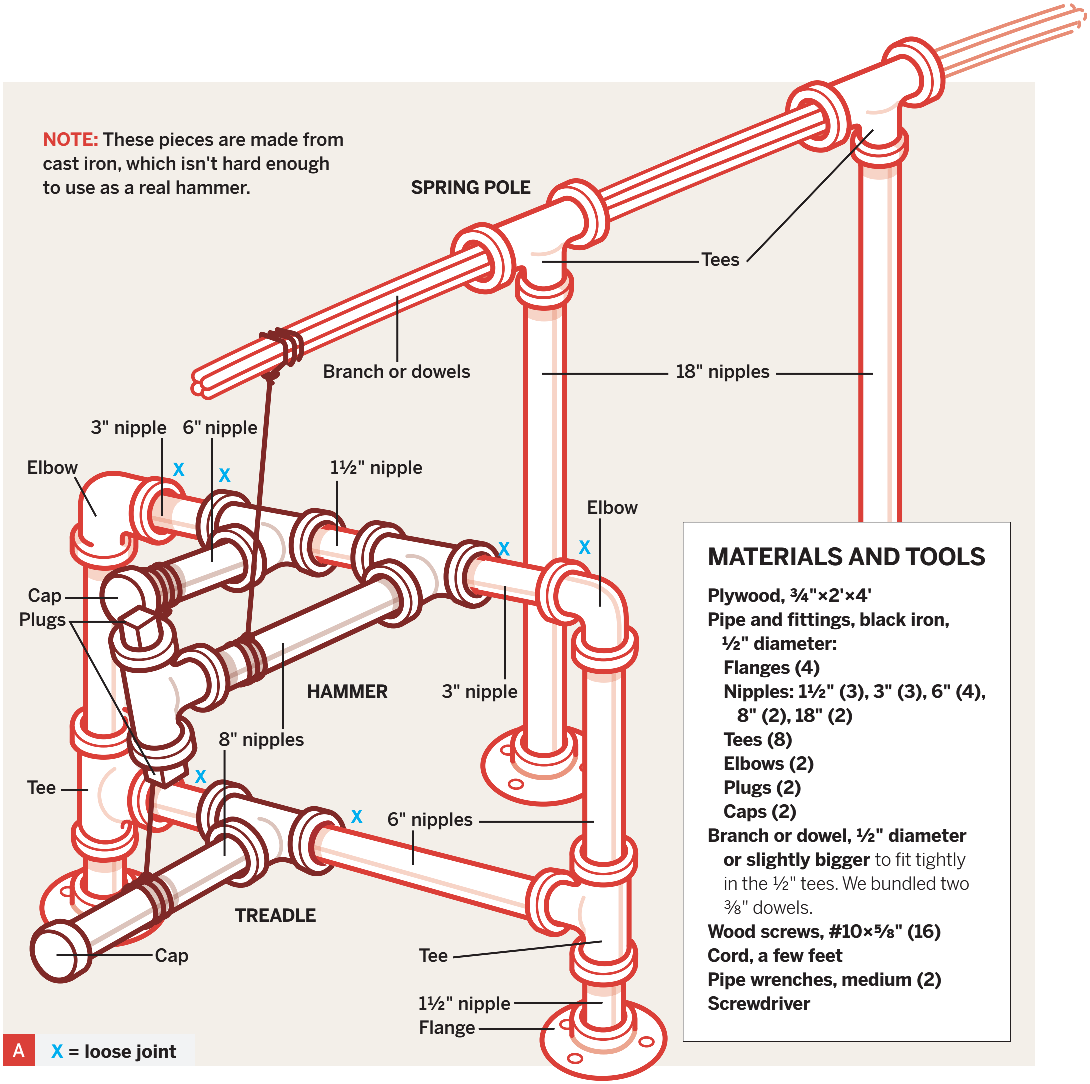
In this project, we'll make a tabletop model Oliver that uses a hand-treadle.

→ START

1. Begin by removing any grease from the black iron pipe with household cleaner. After the pieces are clean, you can lightly reapply pipe grease to the pipe threads if necessary.

2. Assemble the treadle and hammer frame according to Figure A. Start at the bottom, with the flanges, and work your way up. Take note that some connections are to be screwed together tightly and others left loose.

Because all the pipe threads are right-handed, you may find it difficult to screw the last nipple into the last elbow. To work around this, over-tighten the nipple in its tee fitting on the other side, move it into place between the tee and elbow. Then tighten the nipple into the elbow while loosening its connection into the



MATERIALS AND TOOLS

Plywood, ¾"×2'×4'
Pipe and fittings, black iron, ½" diameter:
- **Flanges (4)**
- **Nipples: 1½" (3), 3" (3), 6" (4), 8" (2), 18" (2)**
- **Tees (8)**
- **Elbows (2)**
- **Plugs (2)**
- **Caps (2)**

Branch or dowel, ½" diameter or slightly bigger to fit tightly in the ½" tees. We bundled two ⅜" dowels.
Wood screws, #10×⅝" (16)
Cord, a few feet
Pipe wrenches, medium (2)
Screwdriver

Damien Scogin

tee. If you're careful, this will allow the horizontal shafts to pivot smoothly and easily.

3. Assemble the hammer and attach it to the open end of the upper tee.

4. Assemble the 2 yokes from remaining flanges, 18" pipe nipples, and tees.

5. Fasten the frame and the 2 yokes to the plywood base using #10 wood screws.

6. Assemble the treadle and attach it to the open end of the lower tee.

7. Cut a green branch approximately ½" in diameter (or a bundle of thinner branches) about 3' long. Insert it through the tees at the top of the yokes so that one end is just above the middle of the hammer.

8. Move an anvil or other suitable hammering surface into place below the hammer. Adjust the hammer and treadle tees so the treadle and hammer levers are roughly parallel.

9. Connect the hammer to the tip of the branch with strong cord. You may need to notch the branch to hold the string in place.

Depress the treadle, and the hammer strikes the anvil. Release it, and the spring pole pulls the hammer back up.

William Gurstelle is a contributing editor of MAKE. Visit williamgurstelle.com for more information on this and other maker-friendly projects.

MAKE MONEY
By Tom Parker,
Practical Repurposer

Sometimes it costs more to buy it than to make it from the money itself.

$31.95
Store-bought bell pendant made of nickel silver or brass.

$0.52
90% pure silver jingle bell made from 2 quarters and a piece of dime.

SILVER BELLS

A pre-1965 U.S. quarter buys only one 25-cent gumball from a grocery store machine, but because it's made of 90% silver, its "melt value" is currently closer to $6. So finding a few silver quarters can make digging through desk drawers or old boxes of junk in your attic a profitable exercise. But instead of melting old quarters into $6 silver nuggets, it's more fun to hammer them into something more interesting and valuable. You can make them into silver bells!

There are many ways to hammer a disk of soft, malleable metal like silver into a hemispherical shape. I used an inexpensive metalworker's dapping block and punches, as sold by many vendors online, but you can also pound a quarter into a hemisphere using a rounded hardwood dowel and a dimpled block of oak or maple.

Tap carefully, rotating the coin as you go, to keep the edges of the hemisphere even and symmetrical. A nylon mallet or dead blow hammer will help absorb the impact of your tapping and lessen the bounce-back as you tap. But any hammer will do.

After dapping 2 quarters into hemispheres, you can fashion an eyelet for the bell out of a strip of thinner metal clipped from a silver dime.

And you'll need a clapper for the inside of the bell. I made one by hammering the sides of a steel nail until it had a rectangular cross-section, then sawing off a piece to make a small metal cube.

Once the pieces are roughed out, it's just a matter of filing the edges smooth, clamping the assembled parts in a vise, and sweating them together with a propane torch and silver solder. As soon as the bell cools, you can saw a thin slot using a hacksaw blade, drill relief holes at each end of the slot, and finish the bell with emery cloth and silver polish.

Tom Parker (parker@rulesofthumb.org) lives in Ithaca, N.Y., and works for Cornell University. When he's not tinkering with junk, he flies a 1956 Cessna 180 bush plane.

Tom Parker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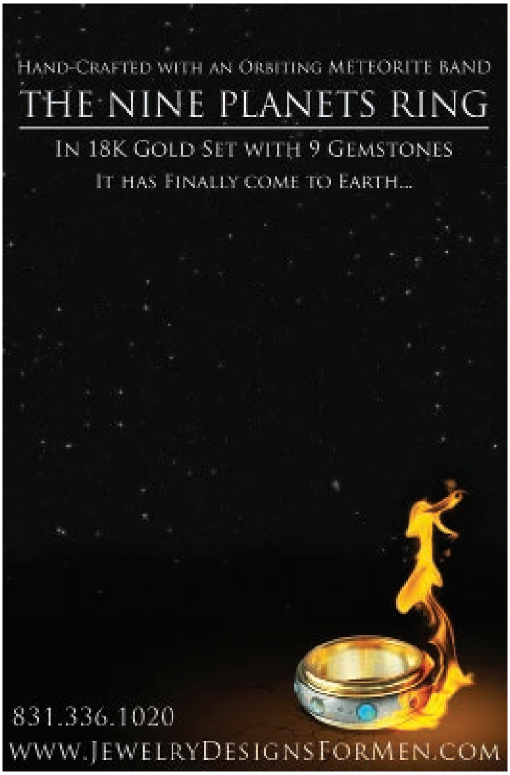

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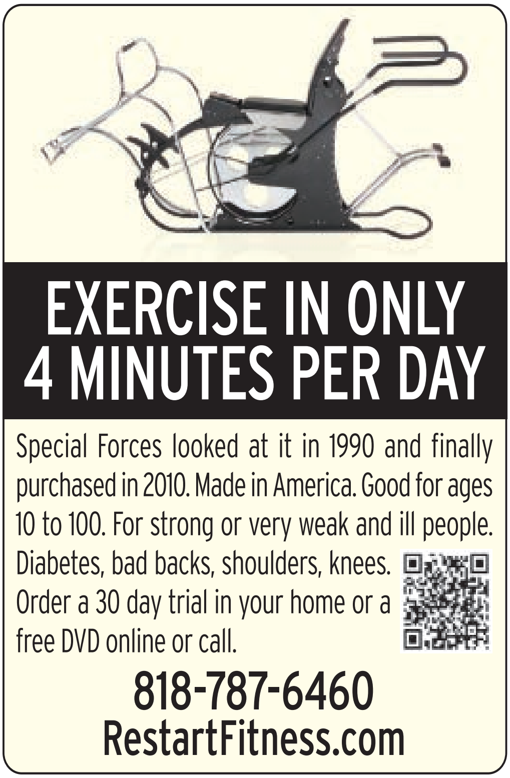
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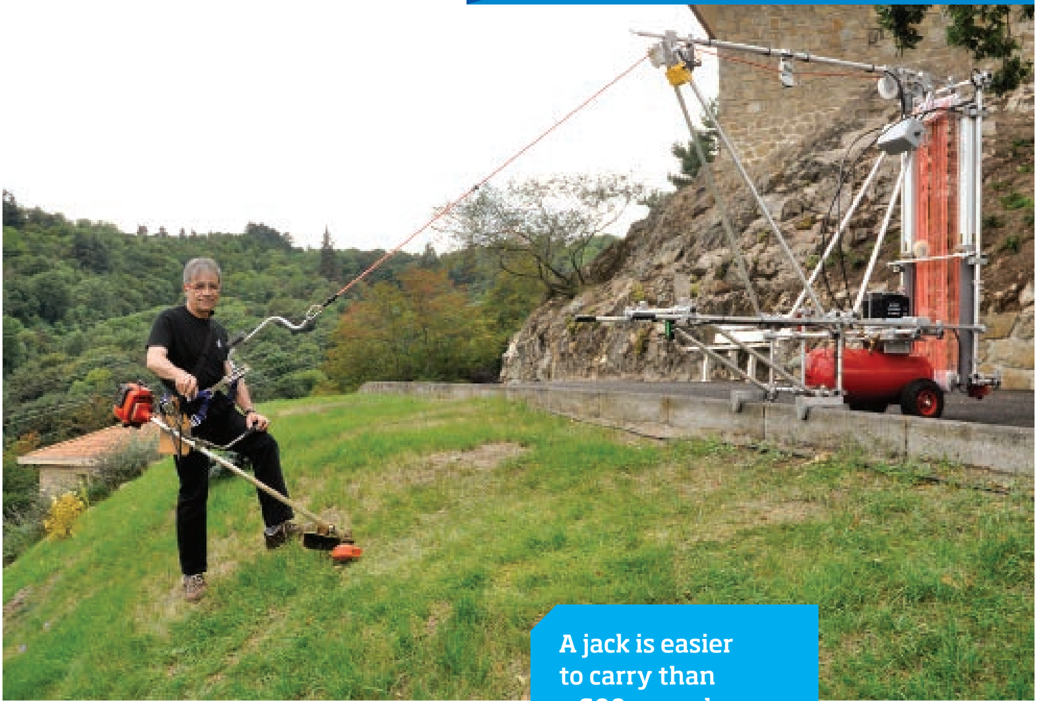
My Own DIY Gravity Balancer

BY GILLES ROBIN



François Grellet

I'M GETTING OLDER, AND IT'S BECOME difficult for me to work on my steep lawn (a 30° slope). I looked for something to continuously pull me up wherever I move or stop, but I didn't find anything to buy on the market. So I decided to make my own device, using two pneumatic jacks that tighten a rope across a series of pulleys. As a Swiss engineer once suggested to me. A jack is easier to carry than a 600-pound counterweight, isn't it?

I started my DIY project with an air compressor reservoir, upon which I attached a frame of aluminum tubes. I then mounted two pneumatic jacks pushing two axles that bear ten pulleys each. Then I wound a Kevlar rope around the pulleys, making ten loops. I inflated the reservoir to 40psi to push the pulleys apart and create a pull of 30 pounds at the end of the rope, according to my calculations.

But when I tried my gravity balancer for the first time, I immediately felt that while the tension was OK when I moved downhill, it was a bit too low when I moved back uphill. Blasted energy losses inside the rope!

A jack is easier to carry than a 600-pound counterweight.

My balancer needed a motor to help with moving uphill. Easy to say, difficult to do!

But everything is working all right now. When I move uphill, a homemade rope tension sensor detects the tension drop and a 24V DC motor starts to smoothly tighten the rope, till I stop it by giving the rope a tug. I can also block the rope using a pneumatic brake. Both servo and brake are HF-remote controlled. The balancer is easy to move, like a wheelbarrow. Thanks to pneumatic jaws, I fix it on the pre-existing concrete curb just with my fingertips. No air refilling or battery recharging is necessary during one day's use.

When I'm using my DIY gravity balancer, people often stop their cars and ask how I got it. You wouldn't ask this, now, would you, readers of MAKE? You'd know I made it myself.

Gilles Robin worked all his life in a research center in Clermont-Ferrand, France. His job was to imagine and create original devices to study physical phenomena on rotating tires.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