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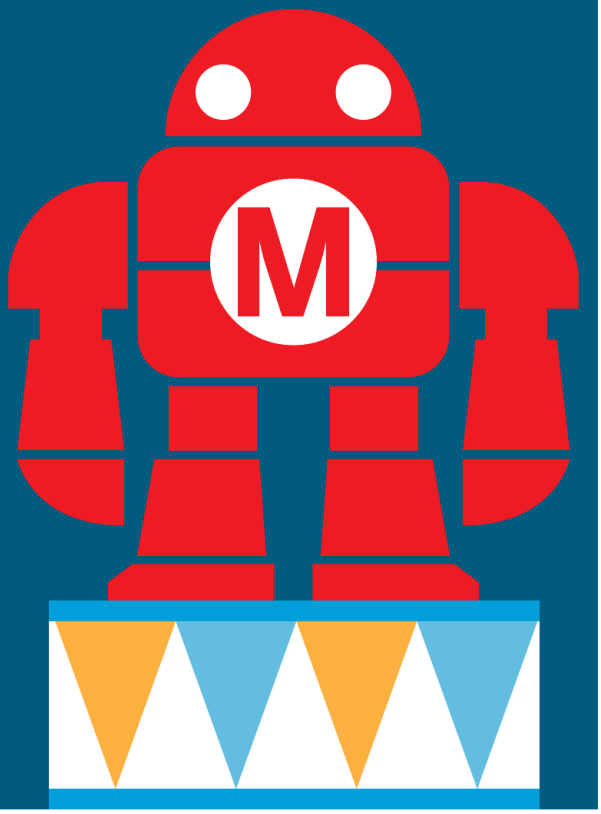

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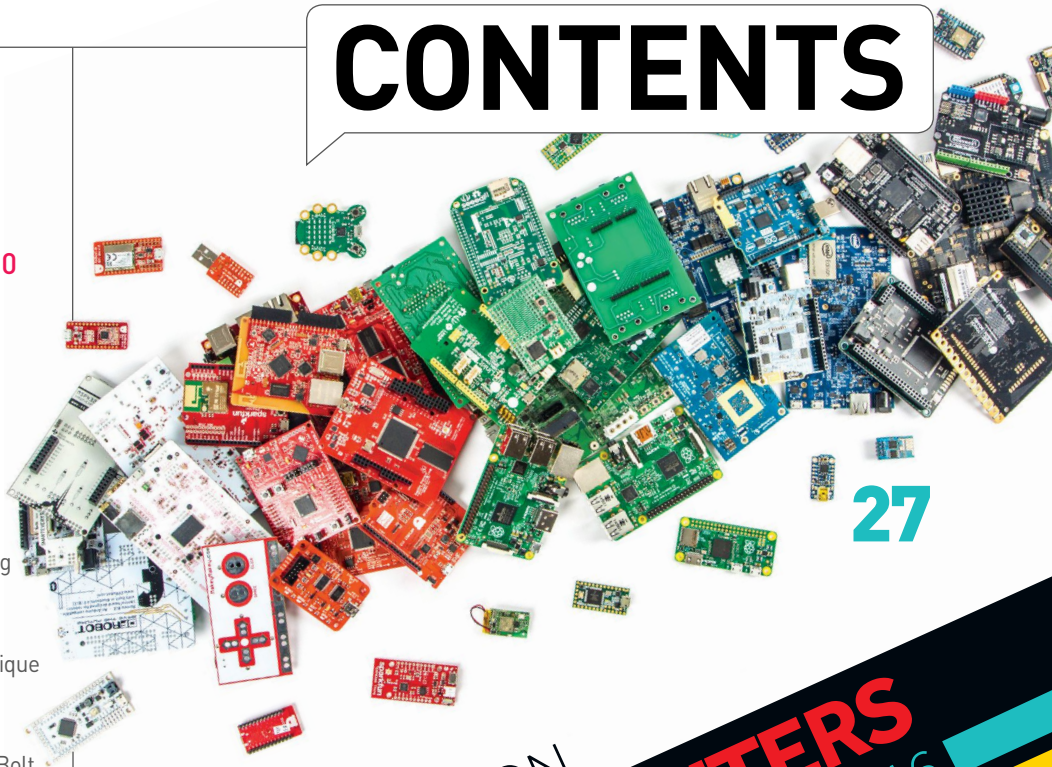

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Issue No. 49, February/March 2016. *Make:* (ISSN 1556-2336) is published bimonthly by Maker Media, Inc. in the months of January, March, May, July, September, and November. Maker Media is located at 1160 Battery Street, Suite 125, San Francisco, CA 94111, 877-306-6253. SUBSCRIPTIONS: Send all subscription requests to *Make:*, P.O. Box 17046, North Hollywood, CA 91615-9588 or subscribe online at makezine.com/offer or via phone at (866) 289-8847 (U.S. and Canada); all other countries call (818) 487-2037. Subscriptions are available for $34.95 for 1 year (6 issues) in the United States; in Canada: $39.95 USD; all other countries: $49.95 USD. Periodicals Postage Paid at San Francisco, CA, and at additional mailing offices. POSTMASTER: Send address changes to *Make:*, P.O. Box 17046, North Hollywood, CA 91615-9588. Canada Post Publications Mail Agreement Number 41129568. CANADA POSTMASTER: Send address changes to: Maker Media, PO Box 456, Niagara Falls, ON L2E 6V2

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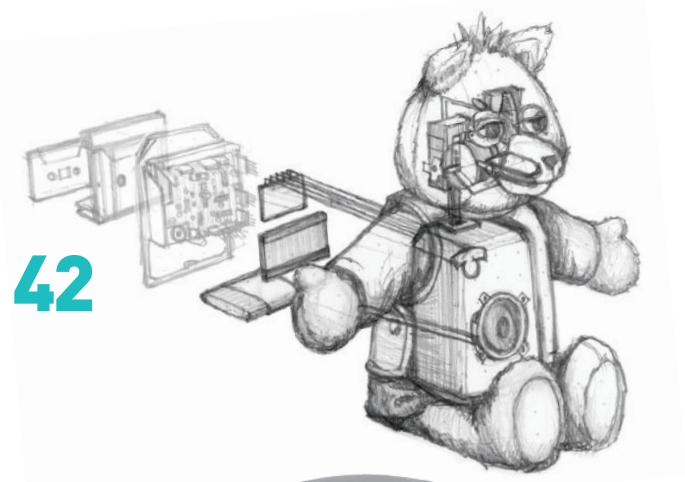

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Damien Scogin

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Make:

GETTING STARTED KIT

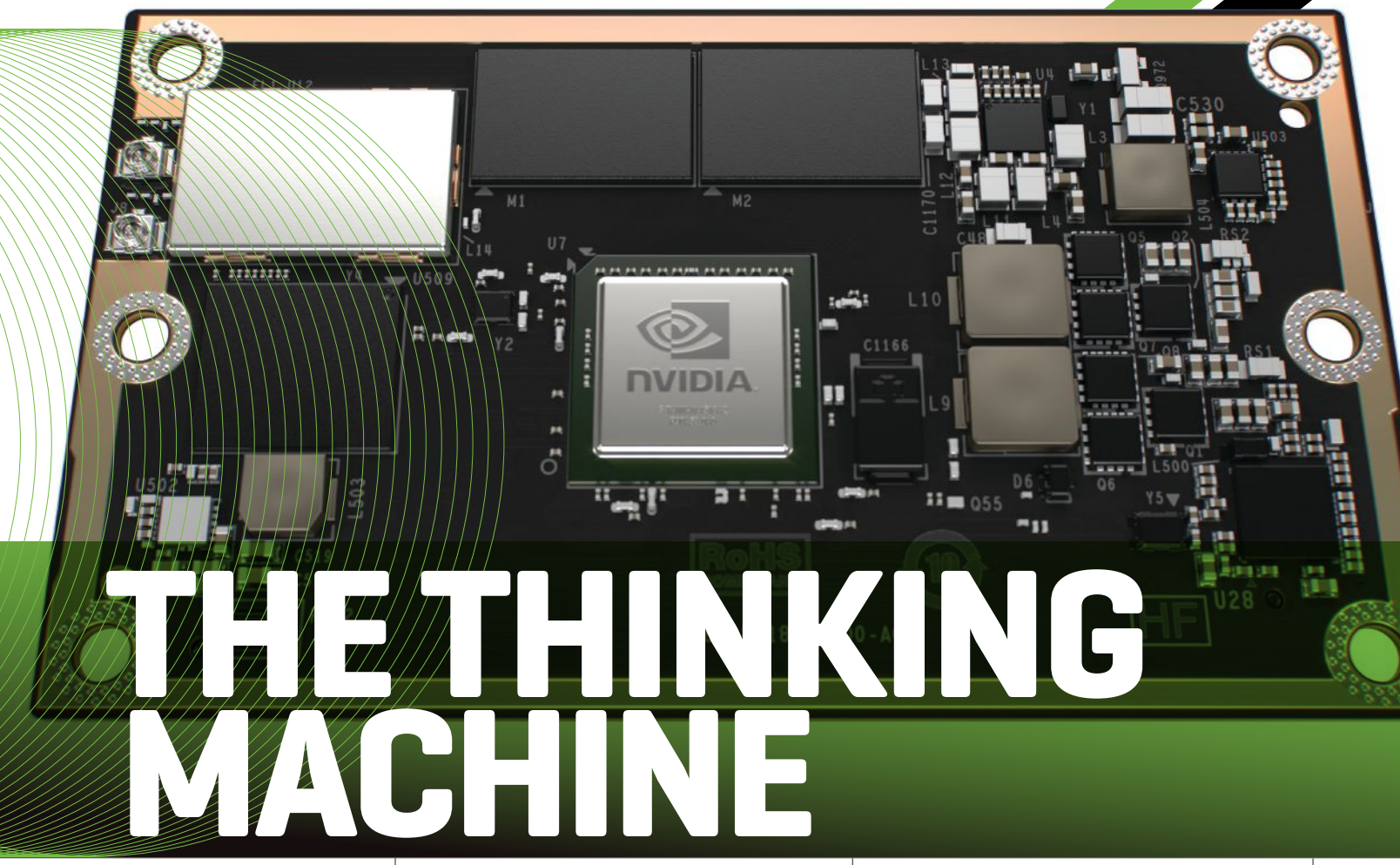
Soldering

THIS KIT HAS EVERYTHING YOU NEED TO START SOLDERING

Learning to solder is a fundamental skill, which allows you to repair electronic toys and gadgets, create your own electronic devices, make jewelry, and more. This kit includes a deluxe soldering station with variable temperature, soldering iron, solder, helping hands tool, a copy of *Make: Getting Started with Soldering*, and even your very first soldering project: a wearable, blinky merit badge that you solder together.

Maker Shed

MAKERSHED.COM/PAGES/KITS



THE THINKING MACHINE

Meet the Jetson TX1, Nvidia's new teraflop-capable board

Written by Patrick Houston

PAUL DOERSCH RUNS A COMPANY THAT MAKES DRONES. But you don't operate his Kespry, Inc., quadcopters with a joystick. You don't operate them at all.

You just give them a few simple instructions from an iPad app that sends them off on their own to survey 100-acre-plus industrial sites, taking hundreds of photos and stitching them together to generate 3D visualizations accurate enough to measure how many tons of gravel, say, is stockpiled on a given spot.

Now Doersch's Kespry — the name comes from kestrel and osprey — is prototyping an even brainier drone, able to process 15,000 images a minute to distinguish in detail pickups, dump trucks, and dozers. It doesn't just see them with cameras, it understands and interprets what it "perceives."

Kespry is developing its proof of concept with the just-debuted Nvidia Jetson TX1 Developer Kit, a tiny, energy-efficient board that operates at super-computing speeds and costs just $599.

In Kespry's drones, and in other devices, the diminutive Nvidia Jetson TX1 is opening the door to a host of interrelated artificial intelligence (AI) advancements, fueling the development of other super-smart "autonomous" devices and Internet of Things endpoints. Here are just a few of the advancements making it possible:

- **NEURAL NETWORKS**, a data processing approach inspired by the human brain, are made of nodes (neurons), connected with each other and organized in layers. Neural networks teach computers how to recognize objects and understand language.

- **DEEP LEARNING** describes the process of using several layers in a neural network to teach a computer how to "learn" over

time. Researchers at companies like Google and Facebook use deep learning to train computers to recognize photos and respond to everyday human language.

» **VISUAL COMPUTING** is a term Nvidia uses to describe everything it does, from enabling detailed computer, gaming, and 3D graphics to providing the fast, efficient graphic processing units (GPUs) for autonomous devices and even data centers. It's about putting images through a processor fast enough for a device to respond on its own — like drones must do to safely deliver an Amazon package to your high-rise apartment patio.

By the way, machines have long been able to learn. But we humans are the gold standard. Even with the mayhem around him, scientists say an NFL linebacker gets it right 94.9% of the time. So do you in everyday life. Five years ago, machines could only get it right 72% of the time. But just this year they surpassed even human recognition capabilities, with a 95.1% accuracy for seeing and classifying images properly.

Because of its commercial potential, more progress will be made, and fast. Machines will soon hit near perfection, which makes for resounding possibilities, such as picking an identified terrorist out of dense crowd.

1 TRILLION OPERATIONS PER SECOND

This Nvidia Jetson TX1 succeeds the company's 18-month-old Jetson TK1. It's two to three times faster, capable of processing up to 1 teraflop. How fast is that? Consider: A flop is a unit of measurement for the number of floating point operations a processor can perform per second. A "tera" is a trillion. That's supercomputer speed, but all in the size of a credit card.

And Jetson TX1 is also energy efficient. Nvidia says it can process 258 images for deep learning every second with less than 10 watts of electricity — about what it takes to power a night light.

The Jetson TX1 also sports general purpose capabilities its predecessor didn't. It comes with Wi-Fi and Bluetooth, along with interfaces that enable it to connect to the same conventional peripherals that laptops, an Arduino, or a Raspberry Pi do.

It's a nod to the broader markets Nvidia wants to target. While the Jetson TX1 is bound to be adopted first by advanced, commercially oriented developers, it's also meant for those "doing those mind-blowing things you see at the Maker Faire," says Jesse Clayton, the product manager who marshaled the Jetson TX1 to its November debut.

The Jetson TX1 is available for pre-order now through Amazon, NewEgg, Micro Center and Nvidia as a $599 developer kit, with an education discount to $299. The module itself will be available next year for $299 each for orders of 1,000 or more.

AFFORDABLE SPECIAL PURPOSE SATELLITE

Besides Kespry's proof of concept, Nvidia says the Jetson TK1 Developer Kit is already being used in other similarly sophisticated prototypes. Percepto, an Israeli startup backed by *Shark Tank*'s own Mark Cuban, is using it to give drones self-navigating capabilities.

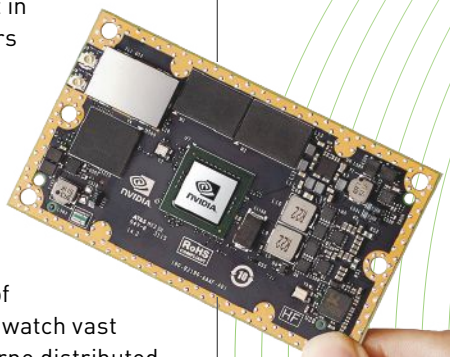
MIT students are using it in small, self-driving race cars that they want to go as fast as 20mph. And the Jibo, a social robot for home use, is powered by one.

Doersch anticipates that onboard supercomputers like the Nvidia Jetson TX1 will one day power a fleet of drones that can constantly watch vast industrial sites as an airborne distributed computing system, each crunching data onboard and cost-effectively streaming it to the cloud, where it can be used for a variety of purposes.

Such a drone fleet would be like giving a company its own affordable real-time satellite, allowing it not just to track vehicles, but to move them when and where they can operate more fuel-efficiently and safely.

State-of-the-art autonomous devices like Kespry's drones will continue to make what was previously impractical even more possible — and far more widespread. And now it's becoming ever more practical and affordable for Makers to create their own super-smart projects, too.

> "With the advances inside the Jetson TX1, Nvidia is also paying heed to those 'doing those mind-blowing things you see at the Maker Faire.'"



The Jetson TX1 is a credit card-sized supercomputer.

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> "Computers can not dream, they can not visualize — that is your part, and that's how you create, innovate, and make a difference."
>
> **— Ravindra Shukla,**
> ***A Maverick Heart: Between Love and Life***

CONTRIBUTORS

What's a device from your house that you wish was a connected device, and why?

Nathan Seidle
Boulder, Colorado [High-Tech Honey]
I've got a 100+ year old house, so I would love to have a device that measures very small shifts in the foundation. Day to day it's imperceptible, but over the years, doors begin to stick.

Dan Royer
Vancouver, British Columbia [DIY Jumbotron LED Wall]
I wish the interior walls, plumbing, and wiring were all modular so I could rearrange the structure — not just the devices — as needed.

Brent Chapman
Cornwall, New York [IoT Security]
I have two small dogs that I leave in their crates. It would be great to outfit them with sensors and an electronically controlled door, in case of fire or other emergency.

Nicole Smith
Berkeley, California [Edgy Glass]
I would love to have a connected oven, so I can cook with more precise settings without having to keep an eye on it, or keep track of the temperature.

Daniel McGlynn
Richmond, California [In Pursuit of Perfection]
I recently built a greywater system, so I would really like to connect my washing machine to soil sensors in my yard to control where and when I'm diverting water.

The **Award-Winning** ShopBot Desktop CNC

We're thrilled to find ShopBot's Desktop named "Best Mid-Size CNC" by *Make:* magazine's *Ultimate Guide to Desktop Fabrication 2016* – "Its combination of volume and accuracy blow the other review units out of the water." Dive a bit deeper to see how all of the reviewed tools, regardless of size, fared against benchmarks of Ease of Use, Software Simplicity, Construction Quality, Flexibility, and Covet Factor. Best total score: the ShopBot Desktop!

What's most exciting to us is how useful this little powerhouse has become to so many hobbyists, design professionals, manufacturers, students and teachers.

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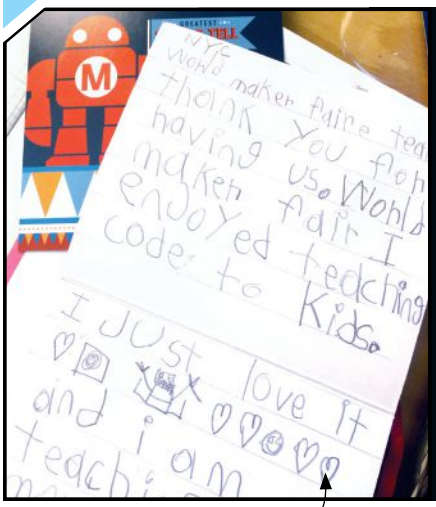


Kedar (aka Little Code Ninja) writes in about World Maker Faire New York.

Big or Small, Maker Faire Inspires

Barnes & Noble hosted Mini Maker Faires in each of its stores Nov. 6-8. That's around 650 Faires!

» I brought my Raspberry Pi and Arduino to the store in Victorville, California and displayed them for all three days. Had a great time, met a lot of interested people.

It was a small start for Barnes & Noble, but a great time for everybody that wants to see more makers and builders! I fully support this new direction for them.

— David Parradee, Apple Valley, California

IN RESPONSE TO "THE ACCIDENTAL MAKER," VOLUME 34, PAGE 52

makezine.com/go/accidental-maker

This article was amazing! It gave me a lot of insight for the underwater robotics course my two maker friends and I plan to take at the University of Wisconsin in Wausau.

This inspired me to build my own bot out of 4" PVC pipe, 2" PVC pipe, an Arduino Uno, and other parts. I'm hoping that the bot can submerge itself down to 12' or more, collect an object, and return to the surface. To date, I'm still working on it, but it is coming along great!

— Jacob Buelow, via email

MAKE AMENDS

In Volume 47's "A Construction Set for the 21st Century" (page 8), W.S. Gilbert was erroneously credited with creating the Erector set. It was A.C. Gilbert who developed the Erector set in the United States in 1913. Thanks to Gilbert and Sullivan fan Lenore Horner for spotting the error!

In Volume 47's "Pocket Automatic Center Punch" review (page 89), the correct URL for the product is generaltools.com.

READER TIPS

IN RESPONSE TO "ACRYLIC CHEAT SHEET: HOW TO CUT, GLUE, BEND, AND MORE," VOLUME 47, PAGE 52

makezine.com/go/acrylic-cheat-sheet

I've tried a couple of different drills on 4mm acrylic and this is my experience:

- Keep speed low. I used around 800rpm when drilling as that was the lowest speed on my drill press.
- Don't be afraid to let your drill bit cut. The material that is removed transports heat away from the drill bit. If you cut too slowly the acrylic will melt resulting in an ugly hole. If you cut too fast (especially with big drill bits) the work piece will crack. If you do it right you get nice long milky white shavings. Too-slow cuts will produce sticky melted stuff around the hole.
- For holes smaller than 4mm you can use an ordinary spiral bit for metal. You don't have to press hard as the drill bit cuts quite aggressively.
- For holes 4mm and up I recommend using a drill bit for glass and ceramic tiles. I've found that ordinary concrete drills work pretty well too. I've successfully drilled holes up to 12mm at 800rpm. If you want to go bigger you will need to decrease the rpm to 400 or even less.

— Gunnar Ostlund, Luleå, Sweden

Author Jordan Bunker Responds:
These are great tips! So long as you go slowly, let the bit do the work, and use lubrication (WD-40 works great), drilling holes in acrylic isn't too much trouble.

• • •

IN RESPONSE TO "LEARN PLASTIC WELDING WITH GIANT INFLATABLE TENTACLES"

makezine.com/go/plastic-weld-inflatable-props

I was making visqueen inflatables using fans in the '80s. If you plan your layout and tape the seams before cutting, you can paint with spray paints and latex on the interior. Then remove your tape and seal up the seams. Voila, decorated inflatable ready to go.

- Some creative use of eagle flasher buttons can make them seem to breath.
- With multiple fans and separate chambers, you can use uControllers to animate them.

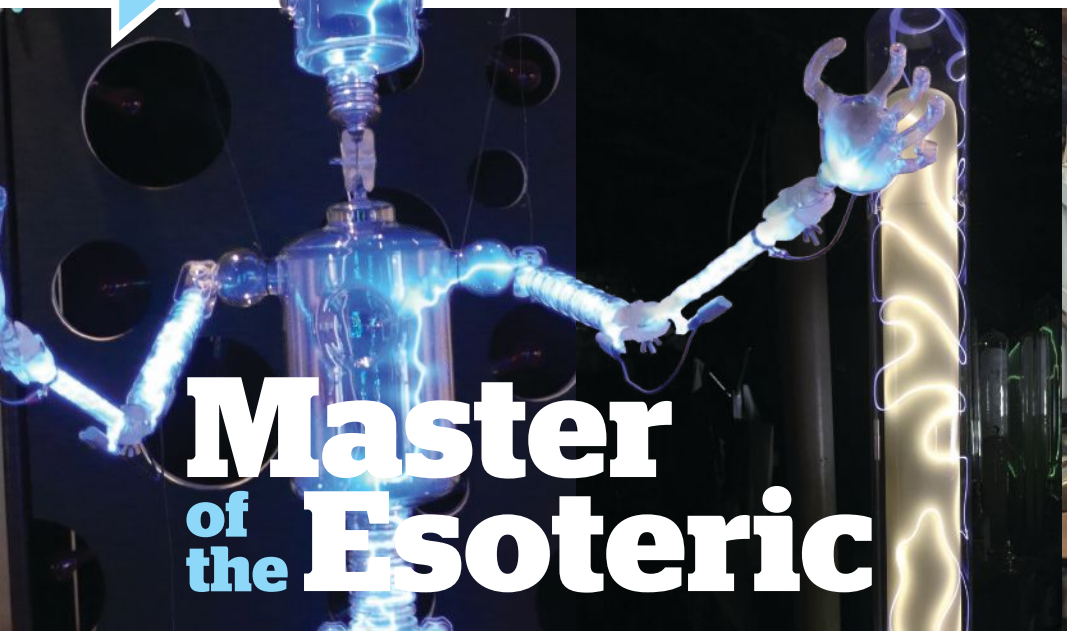
These days, using LEDs for the inside can give you wonderful lighting, much better and safer than low wattage incandescent bulbs available in the '80s.

— Minions Web prop sellers, Bridgewater, New Jersey

Make: Asks

We're fast approaching the 50th issue of *Make:* and we want to hear from you! Tell us how you discovered *Make:* or let us know what your favorite *Make:* project has been. Send a photo or quick note to us at editor@makezine.com with "50 Issues of *Make:*" in the subject line to let us know!

Sherry Huss, Alicia Williams, Gregory Hayes



Master of the Esoteric

BY RAFE NEEDLEMAN, editor-in-chief of Maker Media.

YOU KNOW WHAT REALLY IMPRESSES ME? ROBOTS. In order to make a robot, you have to master several wildly disconnected fields: mechanical engineering, power management, locomotion, radio control, software, and often more. I encourage my son's interest in building robots because it forces him to learn many different things.

But you really cannot predict what other skills robot building will get paired with. The best example of this, for me, is the work of Wayne Strattman, creator of PlasmaBot.

I met PlasmaBot — and Strattman — at World Maker Faire New York in September 2015. I had wandered into the "Dark Room," a spot we have at all our Faires for projects that glow or illuminate. There I was greeted by a 7-foot-tall glowing man made of glass and plasma.

PlasmaBot is a singularly odd and beautiful creation, even for Strattman, a man with a rich portfolio of stunning work behind him already. Strattman has taught himself a collection of esoteric skills probably unmatched by anyone in the world. He is an accomplished glassblower as well as an expert on glowing plasma discharge lighting; before he made PlasmaBot, he invented Luminglas, a plasma lighting display that appeared in *Star Trek: First Contact* and on walls and coffee tables around the world.

Not only is PlasmaBot made of blown glass and filled with glowing gas, it is fully articulated. Each limb is suspended by a wire, and the wires are on a gantry that's currently controlled by a bank of switches.

In all my life I have never seen a plasma-lit, blown-glass marionette before, nor met a person with the bizarre collection of skills required to make one. I suspect I never will again.

LITTLE SHOP OF NOBLE GASES

I wanted to learn more about Strattman and how he came to build PlasmaBot, so on a recent trip to Boston I paid a visit to his shop.

When I arrived, he was fussing over a round piece of flat glass in a giant, circular, 4-foot-diameter custom kiln. Unfortunately, the glass had just cracked. As the cooling glass disk made ominous popping noises, I learned more from Strattman than I thought possible about what it takes to make noble gases fluoresce, and how he is discovering new ways to light them up. (This is his real passion; robot marionettes are something of a side project.)

For example, in Mesmer Tube, a tall glass evacuated cylinder with a small bit of xenon in it, a wavy white line projects onto a white phosphor-coated cylinder in the middle of the tube. The line moves both slowly and randomly, like the movement of wax in a lava lamp, and it's almost impossible not to fixate on it. The line would typically jump around too fast to be interesting, said Strattman, so he grounded the tube, using a "capacitive ground" (another new concept to me). This, he discovered, slowed it down.

The PlasmaBot itself is filled with a different gas: Krypton, at a pressure of ⅐ atmosphere. Strattman blended in a tiny portion of iodine, and it's this mixture that gives it its uncommonly bright blue glow. He discovered this particular formula, he says, after a lot of trial and error.

Strattman is running experiments with gasses constantly, varying the electrical input, the pressure, and other factors. Sometimes he gets good results, but sometimes even the good ones don't last. For example, he discovered that an argon-iodine mix that, when excited by 5,000 volts (DC) pulsed at 60 hertz, will glow a bright emerald green. But it lasts for only 20 to 30 seconds, and then changes to a vague purple discharge. He doesn't know why.

Though Strattman is the master of one esoteric field, he's still experimenting and learning new skills. Gas plasma sculpture has led him to learn suspended robot dynamics, which he hasn't quite mastered yet. But he seemed happy about that. His gift, really, is his insatiable engineer's curiosity and his artist's drive to just keep making. Talking with him, it was very clear that he can't not be making, or learning.

We should all be so lucky.

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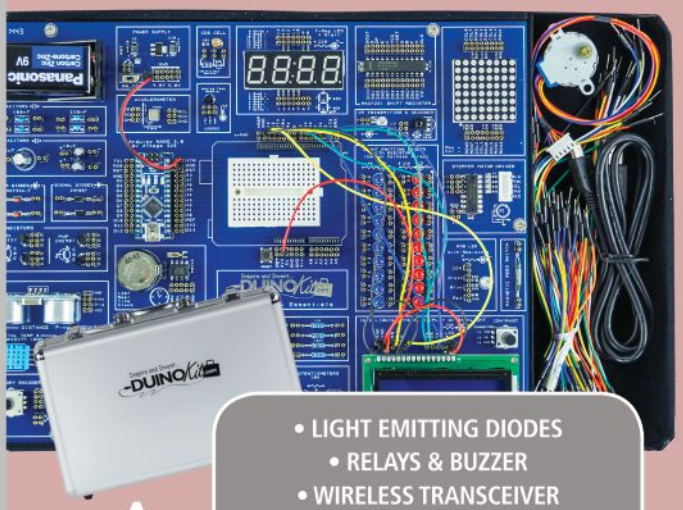

The advanced **Arduino Essentials Learning Kit** is suitable for college or high school learning curriculums. Learn how to read and gather data from input sensors (such as accelerometer, CDS cell, or temperature sensor), process this data and interact with various other output devices. Instructions available online via vendor's web site. Case measures 14" x 9" x 3".

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B) NEW! Duino Jr Kit
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GO FISH

BEN-DROR.COM/THE-ABOVEMARINE

Adam Ben-Dror sought to free his pet betta fish, Jose, from the constraints of his stationary abode. A New Zealand project designer, Ben-Dror created a mobile fish tank that can traverse flat surfaces in the direction the fish happens to be swimming. Known as the Abovemarine, the mobile tank is outfitted with three omni wheels, allowing it to move without the need to turn in the direction the fish is facing. A webcam sits above the tank and tracks the fish's movement in real time, and a computer running OpenCV processes the directional data and moves the tank.

Ben-Dror's designs usually begin with models rather than design programs, which he uses later for refining and finalizing. "My process, which is fairly typical when I work on a project, combines lots of physical prototyping with basic materials — cardboard, wood, acrylic," he says. "I also did some form studies in foam and used CAD to refine the shape and physical design of the tank."

Ben-Dror trained Jose to eat from his hand. Jose learned to focus on what Ben-Dror was holding and follow him in that direction — effectively learning to control his mobile home. Now Jose can interact with other species, including humans and animals, though he had best avoid cats and sushi chefs.

— Cabe Atwell

Adam Ben-Dror

Storms Publishing Inc.

EDGY GLASS

JACKSTORMS.COM

Traci Hedge

Unlike many glass artists, **Jack Storms** likes his glass cool. Compared to more common melted glass blowing or molding, he turns his material cold, on a lathe. Besides needing additional time and expertise, this also required the artist to invent a cold-working lathe to begin with. The device was inspired by Storms' home state of New Hampshire — known as the granite state. He saw that granite could be turned, and wondered, why not glass?

Storm starts with big blocks of leaded crystal, cutting and grinding them, and then inserts dichroic glass for the colored layers. That's followed with epoxy to hold the art together. An external layer of optical glass gives the crystal a floating appearance.

In this unique medium, Storm employs both the golden ratio and the Fibonacci sequence in his designs, giving them a beautiful yet harsh angular appearance. His stunning pieces range from wine bottle sculptures to a crystalline egg called the ViviOvo. And he's still refining both his process and his specialized tool. "I am not close to being done tweaking my new lathe design so I can push the art further," he says.

— Nicole Smith

SEASONED IMAGINATION

RACHELLEREICHERT.COM

Rather than a craft store or art shop, San Francisco-based artist **Rachelle Reichert** harvests raw salt straight from the San Francisco Bay.

Often using water in the place of her own hand, Reichert sculpts salt blocks in high-salinity baths. She grows salt crystals in glue. She experiments with varying proportions of salt and water, and salts of differing coarseness. She places sheets of galvanized steel in pools of salt water until the moisture evaporates. The salt crystallizes, adheres to the steel, begins corroding, and does not stop until the piece has completely self-destructed. As it hangs from a gallery wall, it bends and moves and changes from day to day. The art's very chemical makeup causes it to corrode and waste away.

"Decay and growth are ultimately two sides of the same coin," she says. The entropic process drives Reichert's creative philosophy, which she describes as "Letting go, releasing it, putting it in a format in which we can observe it and analyze it and appreciate it."

— Sophia Smith

Miguel Arzabe

MAKING WAVES

SPECIMENPRODUCTS.COM/DOUBLE-SPINNING-HORN-SPEAKER

Undulating chords bounce out from a spinning, double-horned apparatus reminiscent of a phonograph. It fills the space around it with a Doppler-like effect that layers differing volumes of sound waves before they hit your ear.

The mechanics are simple enough. The rotation is like that of a slow turntable, powered by a flat belt and servomotor. The horn is mounted to a lathe-turned steel shaft that is in turn mounted to tapered roller bearings and spoked brackets, which allow for continual air passage.

"It's an outgrowth from my geometric imagination," says Chicago-based Maker **Ian Schneller**. "The octagonally fluted shapes happen to coalesce, design-wise, with the visual aesthetic."

The spinning double horn speaker, as it's called, has caught the interest of many notable musicians, including Jack White and Andrew Bird, for its curious capability to be both intuitive and magical, almost an instrument in itself. People began to cry in the studio when Bird played through the speaker for the first time, and museum attendees have stayed at exhibits where it's displayed for extended periods of time, even lying down on their backs on the floor to listen to the composition.

"It slows you down and brings you into the moment," Schneller says. "It transports you that way, because there's really no escape."

— Sophia Smith

Eric Futran

Grime Fighters

A NETWORK OF DIY ENVIRONMENTALISTS IS HELPING MONITOR CLEANUPS AND BUSTING POLLUTERS

Written by Benjamin Preston

BENJAMIN PRESTON is one of the few journalists to hold the dubious distinction of having been an alignment technician at a Pep Boys in Fredericksburg, Virginia, as well as an automotive reporter for the *New York Times*. In addition to the *Times*, he has written for the *Guardian*, *BBC Autos*, *Car and Driver*, Jalopnik, and, he is very proud to say, *Petersen's 4-Wheel & Off-Road*.

Occasionally, on a dark quiet night, the streets of Brooklyn, New York's Gowanus neighborhood are the backdrop for an unusual environmental investigation. A middle-aged man and a teenage girl hunch over a closed manhole cover, holding a wire protruding from a small hole in it. This is Eymund Diegel and his daughter, Amara, his assistant on nocturnal explorations to sleuth the source of underground streams.

To do that, Diegel and Amara, 13, lower a secondhand lavaliere microphone — the kind television stations clip to lapels for interviews — through a small hole in the manhole cover. Using free iPhone apps, they record the sound level of the water flowing below. Diegel only listens at certain manhole covers, but his goal is to get readings for every hour of the day at each one.

Diegel is a board member for Public Lab, a nonprofit confederation of citizen-scientists dedicated to using open source hardware and software to bust polluters and other environmental bad actors. The organization first made a name for itself by mapping the BP oil spill's impact on the Louisiana coast using hacked balloon- and kite-mounted digital cameras. Then it started making DIY kits that allowed people trying to solve environmental and community problems in other places, to use their basic aerial-camera technology. Their simple technique has helped people all over, including people like Diegel, who first became interested in the Gowanus Canal because of his passion for canoeing.

Diegel calls what he's doing CSI: Gowanus. (CSI stands for "creek scene investigation.") He says the underground streams he's looking for were covered up as this corner of the city developed, transforming farmland into the concrete-skinned industrial zone it is today. The backbone of the neighborhood is the Gowanus Canal, a 1.8-mile-long industrial waterway and EPA Superfund site, the mere mention of which causes many New Yorkers to cringe in disgust.

The U.S. Environmental Protection Agency has plans to dredge the toxic sludge from the bottom of the canal and seal it off to prevent the deeper-seated pollutants from seeping into the waterway, but Diegel says he wants to make sure the job is done right. That's where his CSI project comes into play. New York is equipped with a combined sanitary and run-off sewer system, meaning in times of overloading — like during severe rainstorms — sewage and storm water can both overflow into outlets like Gowanus. Diegel believes underground streams are, like rainstorm runoff, also overloading the city's sewer system, pushing sewage into the already-polluted canal through the combined overflow system.

Eymund Diegel/GLAM

Where many people would write off extra water rushing beneath a manhole cover as human activity — toilet flushing, dishwashing and the like — Diegel noticed, thanks to his microphones, that water can also be heard at night, when most people are in bed. So he suspects the natural world has a hand in the problem. To find which manhole covers he should drop a mic into, he used an old digital camera mounted to a big red balloon, looking for large trees and unusually dense clusters of vegetation as close sources of water.

"We got the digital cameras from an e-waste center nearby," Diegel says, adding that Public Lab distributes an open source hack script that takes over the camera's operating system, making it possible to use it in a way its designers may not have anticipated, such as snapping pictures every 5 seconds while it's aloft, dangling from a balloon. "Sometimes we hack the cameras to take infrared pictures, which are useful for spotting vegetation."

Diegel does all this for free, in his spare time. But his day job is related: He maps potholes for the city's department of transportation, and says that the places potholes are found often coincide with underground streams.

"The sinkhole that opened up in Brooklyn over the summer was at the headwaters of the Dyker Canal," he says, referencing a long-covered waterway he had learned of by studying centuries-old maps. "The city said it was because of a water main break, but I wanted to know what had caused the water main to break."

In addition to his informal field research — eavesdropping on sewers and knocking on doors and talking to people — Diegel relies on the data sharing and open source gadgetry championed by Public Lab.

Gowanus Low Altitude Mappers/Gowanus Canal Conservancy/Public Lab Aerial Mapping Program

"Open source also allows technology to become more accessible from a democratic cost perspective," Diegel says. "Our consumer products, including those we use to view science and our neighborhoods are increasingly 'closed black box' products over which we have no control or input. We often don't know how they work or how to repair them."

BORN FROM OUTRAGE

Public Labs emerged in 2010, as outrage over the BP oil spill in the Gulf of Mexico began to mount. Its founders — a group of Gulf Coast residents, environmental advocates, and scientists concerned about the spill's impact — wanted more detailed information about the movement of oil across the coastlines of Louisiana and other Gulf states. If the oil company was talking, they weren't satisfied with what it had to say. They launched digital cameras into the air on balloons and kites all over the region, using software to stitch the images together and form a more complete picture of what was happening.

What started as grassroots mapping morphed into a long-term project to facilitate monitoring other problem areas. Public Lab has expanded farther afield, helping citizen-scientists map industrial pollution in Spain, air pollution in Ukraine, and forest canopy loss in Peru, among others. Thanks in large part to Public Lab's collaborative spirit, the list of projects the organization's techniques and open source kits have touched is seemingly endless.

"Public Lab is a large community, so it's hard to say how many different things are going on," says Liz Barry, Public Lab's director of community development. "We try to count the number of environmental investigations underway, because that's kind of the sum of all the community organizing that means people actually impacting their local environments."

This kind of monitoring, and the equipment used for it, can be expensive and therefore difficult to access. The cutting edge in monitoring technology could certainly be helpful, but it only works if there's someone who can use it. So Public Lab devises cheap hacks and open source software that's accessible to all. The gadgets it relies upon for data collection include things like obsolete digital cameras, used DVDs, cardboard, and old soft drink bottles. When aerial photography is needed, Public Lab is much more likely to use plastic kites and helium-filled balloons than military-spec drones to carry its cheap camera equipment aloft.

Simplicity is the core of what Public Lab does, but so is sharing information. According to its website, Public Lab's tools must be "low cost, open source, easy to use, built through public participation and collaboration, supported by a network of practitioners, [and able to] produce meaningful, understandable, and high quality data."

INCLUSIVE AND ACCESSIBLE

To give concerned citizens and community groups access to the tools they need to illuminate environmental problems, Public Lab sells low-cost DIY kits for everything from balloon mapping rigs to spectrometers designed to monitor water pollution.

"Our balloon kit was our earliest kit," Barry says. "It's been applied to a million different situations — oil spills, invasive species mapping, social protest."

The kit contains, among other things, a neoprene balloon, a reel of fishing line, instructions on how to make a camera rig from a 2-liter soda bottle, rubber bands for the camera rig shock absorber, a grassroots mapping guide, and a balloon mapping flight checklist. Some cameras need to be modified to take pictures at five-second intervals, and others have a setting for that.

The interest in petrochemicals, which Barry says are a frequent player in environmental pollution scenarios, led to the development of the spectrometer kit. It started as a repurposed pizza box, cut up to hold an old DVD and a cheap webcam, then morphed into a DIY kit that could be purchased online. Public Lab says on its website that the materials to build a spectrometer cost less than $15. Detailed online instructions show how to cut up opaque black cardboard to make a small box, where to position the camera inside the enclosure, and how to peel the backing from

In 2013, a dolphin died in the Gowanus Canal. Experts said the animal was already sick when it entered the canal.

Eymund Diegel

KITTING UP

Open source tools from Public Lab and what they do

DESKTOP SPECTROMETRY
A webcam records light from a narrow gap, like a slit camera, filtered through a diffraction grating made from an old DVD. It can measure the wavelength of light in both air and water.

INFRAGRAM
You can remove the infrared blocking filter from an old digital camera and replace it with a blue light filter to get images from the infrared wavelength. The images can analyze foliage, including how pollution affects chlorophyll production.

WHEESTAT
Still in alpha, this potentiostat determines concentration of metals in water by measuring the reactions of electrons in solution. It can identify lead, arsenic, and mercury.

KAPTERY AERIAL CAMERA MOUNT KIT
If you're going to dangle a camera from a kite or a balloon, it helps to have a bracket like this. A suspension rig keeps the camera oriented, and it attaches via a tripod mount.

RIFFLE
This water quality sensor, housed inside a 20 oz plastic bottle, gets dangled into bodies of water, measuring temperature, conductivity, depth, and turbidity (how cloudy the water is). Sensors like a thermistor stick out through the cap, and it logs the data on an Atmel328P.

See these and more at publiclab.org.

a DVD-R and place it against a narrow slit to form a diffraction grating. Using a dimmable lamp to shine light through a water sample, an at-home scientist can measure light wavelengths down to the nanometer using Public Lab's open source software.

The power of that measurement is in distinguishing hydrocarbons like oil and other contaminants. Public Lab is crowdsourcing a DIY method for that analysis with the help of chemists from its community. "The magic is in the collaborative environment Public Lab enables among so many different — and often siloed or unrecognized — forms of expertise," Barry says, adding that academics are often happy to lend a hand. "The diversity in the type of expertise that is leading any given project is what keeps the barriers to entry low and keeps projects inclusive and accessible."

Barry says it can be difficult to identify unknown contaminants, but as data comes in, it's scrutinized by actual chemists and added to a database. The idea is to fill in the gaps, so to speak — to make it simpler to infer missing information from known values. "This could be like a Shazam for chemicals," she says.

Other kits from Public Lab include a filter that helps convert digital cameras to infrared, a potentiostat to determine metal concentrations in water, and an Arduino-driven datalogger for a plastic water bottle that can record temperature, conductivity, depth, and turbidity in water. "Temperature data has been used to shut down a nuclear power plant before, so a lot of communities are interested in that one," says Barry.

SPREADING THE WORD

DIY hacks aren't the final answer in Public Lab's battle against pollution, co-founder Matthew Lippincott points out.

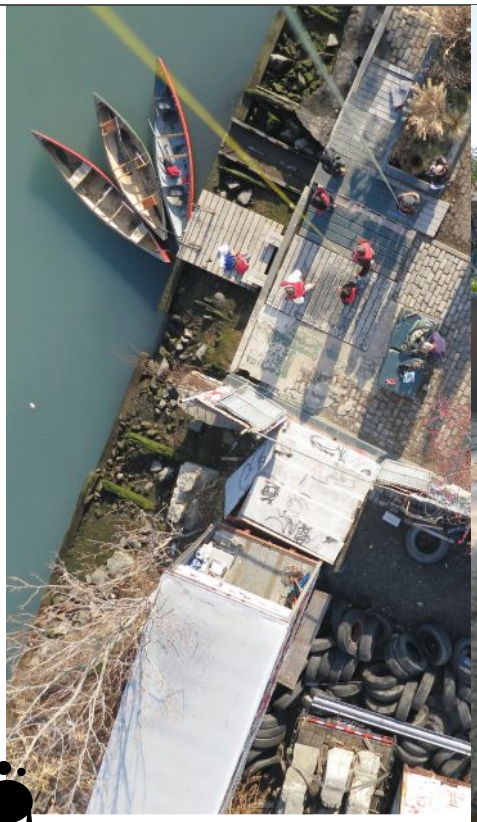
"It's not always about the gadget," he says, adding that sharing information and telling community groups who to talk to are invaluable tools in the organization's work. "Simple photos sent to an environmental health department can be really helpful."

The pollution seen by a fisherman on Louisiana's Gulf coast may share similarities with pollution on an industrial canal in Brooklyn, but there will invariably be differences in what works and what doesn't. That, Public Lab participants explain, is why sharing information about process is as important as allowing each person to contribute his own input to each approach.

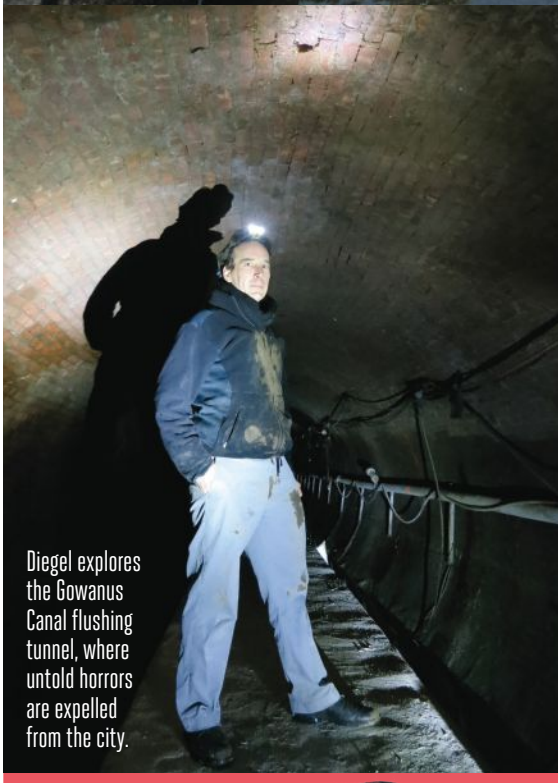
When a guy in a canoe who's concerned about the water he's paddling through wants to know more, he gets in touch with someone who knows what questions to ask, and how, and adapts them to his own situation. The same thing for a woman who smells oil fumes, but can't figure out where they're coming from.

By making it fun, with activities such as finding the "birthplace of the Teenage Mutant Ninja Turtles" (a nuclear waste pollution site in Queens), Diegel says he hopes to engage more people.

"Open source dialogues and the Maker ethos re-establish some of the fundamental building blocks for cultural evolution in our increasingly technology-dependent world," Diegel says. "It's also a fun excuse to fly big happy red balloons and kites, and meet interesting people doing cool stuff."



Amara surveys the Gowanus — and the rat carcasses within.



Diegel explores the Gowanus Canal flushing tunnel, where untold horrors are expelled from the city.

GLAM/Gowanus Canal Conservancy/Public Lab Aerial Mapping Program, Eymund Diegel, Steve Duncan

GET IT NOW

The Public Lab spectrometry kit is in the Maker Shed: makershed.com/products/diy-desktop-spectrometry.

IN PURSUIT OF PERFE

HOW A TOOL-OBSESSED VETERAN RE-CREATED ANTIQUE HANDSAW DESIGNS

DANIEL MCGLYNN is a writer based in the San Francisco Bay Area. He shares a small workshop behind his house with his two kids.

Mark Harrell

CTION

Written by Daniel McGlynn

DURING HIS LAST DEPLOYMENT AS AN ARMY OFFICER, in 2007, Mark Harrell was in command of a team tasked to train Afghan National Army forces to better fight insurgents. He valued the work, and his comrades, but throughout the tour of duty there was one thing that his mind kept coming back to: traditional backsaws, the kind with a stiff back, used to make fine cuts in detailed joinery and furniture making. One in particular, a hand-built backsaw made by a family-run outfit in Oregon, consumed his attention, and he resolved that when he got home he would add it to his collection. It was just a tool he wanted to buy, but it would become so much more, setting him on a path to the forefront of a growing movement of woodworkers and tool builders who champion the merits of near-forgotten designs and build techniques.

Long before he set his sights on the backsaw, Harrell started collecting old hand tools as a hobby. He would visit eBay looking for vintage tools in his price range. Then he noticed that tools that needed a little work, some rust removed or a new handle, could be bought cheaply, fixed up, and then resold at a profit.

Eventually Harrell discovered handsaws. "Having a sharp saw that will sever a board the exact way you want it, with that buzz sliding up your arm, you become addicted," he says. "Before you know it, you're buying saws on eBay and sneaking them past your wife."

By taking apart and reviving old saws, Harrell was also getting a design education. Inspired and informed, would go on to start, in 2009, a small manufacturing company in La Crosse, Wisconsin, called Bad Axe Tool Works, which is now one of the premier small American saw companies.

THE UNPLUGGED GOSPEL

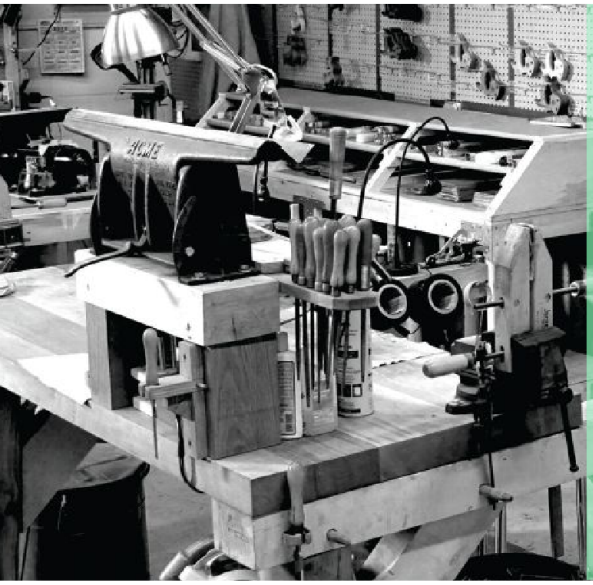
Tom Fidgen, a writer and professional furniture maker in Toronto, exemplifies the obsession that hand-tool makers and restorers like Harrell possess and cater to. A widely recognized evangelist for handcrafted woodwork, Fidgen is the author of *The Unplugged Woodshop* and founder of The Unplugged Woodshop, a studio and school in Toronto that features classes on how to use hand tools and what you can make with them. He started building with hand tools only when he moved to Toronto in 2008 and didn't have the space for a workshop with large tools. Then he realized he preferred hand tools anyway. "At some point, working with hand tools became its own thing and I started writing about it, and talking about it, and teaching classes all over the planet," he says.

"Seventy percent of my students are desk jockeys that work in an office all day," Fidgen says. "When they get home they don't have a whole lot to show for it." So they head to their garage, or basement, or shed, and get to work building something by hand. Low-tech building can be done practically anywhere, at any time. And using hand tools is a more tactile experience: A Maker can hear, feel, and sense subtle changes in a workpiece. The result is that no two things made by hand will ever be exactly the same.

The attraction of traditional craftsmanship, and the demand for

high-quality tools, are directing experts like Fidgen toward traditional toolmakers. "There are boutique places popping up all over, like [Harrell's]" Fidgen says. "He's one of the most well-known saw makers in the United States, but it wasn't that way five years ago. Before, he was just one guy sharpening saws in his basement."

After his deployment to Afghanistan, Harrell retired from the Army and perfected his saw sharpening technique. He built a website in 2008 and started advertising his restoration services. At that point, he still thought of saw restoration as a side project — something he could do to make enough money to support his own tool buying habit.



"YOU BECOME ADDICTED. BEFORE YOU KNOW IT, YOU'RE BUYING SAWS ON EBAY AND SNEAKING THEM PAST YOUR WIFE."

Harrell wrote to Chris Schwarz, at the time an editor at *Popular Woodworking* and a well-regarded voice among hand tool enthusiasts, explaining his sharpening technique. Schwarz sent Harrell a saw to sharpen, and happy with the results, blogged about Harrell's fledgling operation. And woodworkers noticed. In the weeks that followed, Harrell found dozens of saws shipped to him, waiting on his doorstep in need of attention.

It didn't take long for him to feel like he stumbled onto something he could shape into a second career. "I looked at my basement workshop, and realized I wasn't the only one doing this," he says. "I realized the market was really deep."

TRADITIONAL MEETS HIGH-TECH

Years have passed since Schwarz first wrote about Harrell's prowess, and since then Schwarz too has tapped into the growing unplugged workshop momentum. He now runs a small book publishing company called Lost Art Press that specializes in books about traditional furniture making and building methods. Schwarz wrote and published a book called *The Anarchist's Tool Chest*, in which he makes the case that a well-appointed woodshop only needs 50 good quality hand tools to build just about anything out of wood, using traditional methods.

During a question and answer session earlier this year on the 135,000-member r/woodworking subreddit, Schwarz was asked about the noticeable resurgence in hand tools and traditional woodworking — why was this happening now?

"There is no doubt that the internet has allowed us to find one another," he wrote on reddit. "When my dad and I were building houses in Arkansas with hand tools, we thought we were alone. The internet proved us wrong. Second, the availability of new quality hand tools has spurred an interest. People who don't enjoy tool restoration (I'm one of them) can focus on woodworking rather than metalworking. That's huge. More toolmakers creates more woodworkers creates more toolmakers. Until we saturate."

While hand tool enthusiasts and craftsmen have been communicating online since early chat rooms, the latest social media platforms make it still easier to connect, share information, and resurrect tools that might otherwise be seen only in rusty piles at flea markets and antique shops."

All of this served to set up Harrell, and others like him, to enter the market at a perfect time. As the interest and demand for high-quality tools, made to exacting standards and sold at a premium price, was ripening, Harrell was restoring loads of saws.

REDISCOVERING A CLASSIC

At work in his basement, Harrell explored American saw-building innovations in materials, like steel quality, and changes in design. He was able to figure out what

saw set-ups endured over time and what modifications users make to handles (saw makers call them totes) and how different kinds of teeth are filed. He restored saws from some of the world's best makers, such as Simonds and Atkins.

Before long he found himself developing a particular affinity for saws designed by Henry Disston in the years following the American Civil War. Saws manufactured by Disston (later Disston and Son, and eventually Disston and Sons) are still in demand. The saws represent a benchmark of technological advances, particularly in steel quality and overall craftsmanship, that modern toolmakers struggle to equal. Harrell started studying Disston and was pulled in by his life's story and his drive to make an exceptional product.

Disston did not have it easy: As a young teenager, he immigrated to the United States from England with his father, who died three days after their arrival. A young Disston found a job as an apprentice saw maker. When his apprenticeship was over several years later, he was paid with tools and supplies instead of cash.

Disston went on to build a small empire, but not without having to start over numerous times because his factories kept burning down, and because of other personal calamities. Along the way he made several important saw innovations. He became the first American saw maker to smelt his own steel for blades. And the skewback handsaw design, the style of carpenter's saw that tapers toward the tip — the kind most people probably have hanging from a pegboard over their workbench — is attributed to Disston. He also treated his employees well, eventually building a company town for them outside of Philadelphia.

THE AMERICAN KID

During his self-directed restoration education, Harrell also kept thinking about the backsaw he bought when his tour of duty was over — the one his mind wouldn't let go of while he was in Afghanistan — and his experience when he got it in his hands. "It was underwhelming. I thought I could do a better job than this," he says. "My background from the Army makes me competitive. There is no substitute for consistent excellence; you can't make a damn thing happen unless you are consistently excellent. Everything better look cool and be squared away."

Using Disston's designs as a starting point, Harrell moved beyond saw restoration and sharpening and moved into actually manufacturing new tools. He studied the designs he liked best from his restoration experience. "When I developed Bad Axe I either copied or made small adjustments to traditional designs," he says. "You don't have to reject the old to embrace the new."

The first step was making prototypes and then having them modeled with a 3D scanner. Then he found craftsman capable of making high-quality components: The steel for the blades is ordered from a steel manufacturer and cut to the correct size. Harrell's shop grinds and sets the teeth, and then sends it out to a gunsmith for a blue steel treatment, and to have the company logo laser etched on it.

He named the company for a river in Wisconsin, and for a battle that took place there in 1832. The five-mile Bad Axe forms where two streams braid together before entering the Mississippi River. It's also the last battle fought east of the Mississippi between Native Americans and U.S.-backed militias. Harrell was taken with the resistance shown by the group of Native American fighters — they inflicted heavy causalities on their attackers — even as they fought on the losing side of a massacre.

Harrell sold his first Bad Axe saw in July 2009, and has been working ever since to perfect a decidedly American saw. He now offers 10 models of backsaw, including tenon, carcass, sash, dovetail saws, and more. (The names reflect the kind of joinery or application that they are made for.) Harrell's saws are customizable to individual customer specifications and intended use. He even makes a small and durable backsaw designed for kids, fittingly called the "American Kid."

CHASING HENRY DISSTON

Harrell says he is trying to figure out how to manufacture a more general-purpose handsaw, without the stiff back, suitable for ripping thick stock, or for crosscutting big pieces quickly. "We are actively in research and development to reproduce the classical handsaw that was perfected in the 1900s. It has a dual compound taper grind. The tooth line is thicker than the spine in the center. You have to get the grind just right, and then you have to make it stiff again after you grind teeth. No one has been able to do that since before World War II."

In the meantime, as a reminder of Disston's influence and legacy, Harrell hung a large banner in his La Crosse workshop where he and a handful of employees assemble, tune, sharpen, and test Bad Axe's saws before shipping them to customers.

The banner reads, simply: "What would Henry do?"

Maker Pro File

Ben Einstein

Written by DC Denison

Notes, numbers, and advice from professional Makers

BEN EINSTEIN IS AN EXPERIENCED PRODUCT DESIGNER AND INVESTOR. He is currently the managing director of Bolt, an early stage seed fund focused exclusively on hardware startups. In addition to seed capital, Bolt invests full-time staff, shop equipment, and extensive expertise in manufacturing and commercialization. Prior to starting Bolt, Einstein ran Brainstream Design, a product design and development consultancy in Massachusetts. He has been directly responsible for bringing to market a long list of products (the products' identities are under nondisclosure agreements), covering diverse sectors including consumer electronics, high-performance audio, sporting goods, and green energy.

ADVICE

Speed can kill Sometimes it's good to go fast, sometimes it's not. You have to be strategic, you have to figure out how you'll tweak the product in the early stages. So be cautious about coming out too fast.

Don't hire a design firm This one gets me in trouble, but when you hire a design firm you are outsourcing the most fundamentally valuable work you do as a company: building a product that people love.

BEWARE ...

The long shadow Decisions that you don't think are decisions at the time — This Bluetooth radio or that one? — cast a shadow that lasts for months or years. If you pick the wrong microcontroller, or one with not enough RAM, it can haunt you forever.

Cowboy engineering Hardcore engineers use this term to describe flying by the seat of your pants. Some people do it well, but if you want to build a product for the masses that works reliably, you have to be rigorous about testing the product while you're in development.

Crowdfunding Kickstarter is very appealing but extremely dangerous if you don't use it correctly. You are amplifying all the decisions you made — in a cowboy style with long shadows everywhere. You're broadcasting to the world and you haven't figured out what your retail price is going to be, what your bottom-line costs are, how and where will you manufacture, and so on. Go through product development and early manufacturing first, and then use Kickstarter to launch. That works much better.

IMPORTANT NUMBERS

Venture capital Ask yourself if this is even what you want. A typical VC investor is looking for a company that will be making **$100 million** in revenue within five years of initial investment. That's a lot. Most companies don't get there. A VC invests in **20 companies**; maybe **two** will be successful, but the success is so big it will pay for all the failures.

Prototypes Make **one prototype** a week. People forget to build stuff. They get caught up in the idea of perfection; they want something to be perfect, moldable, beautiful, before anyone uses it. But you don't need to build a fully functional product before you can start getting feedback.

How much feedback? Talk to about **30 people**, not including your mom. **Five people** isn't enough, more than **50** takes a lot of time.

First run, minimum order If you want to build any product in China that's fully assembled, it's hard to do that with fewer than **5,000 units**. The factories don't make money on the setup; they make it on the volume.

Validation **Three stages** are critical in the validation phase of building, and they're not fun: engineering validation test (EVT); design validation test (DVT); and production validation test (PVT). These things are complicated, but if you don't take the time for testing, you fail.

A SHOUT-OUT TO DAD

I've always been a tinkerer, a basement kind of guy. That comes from my dad, who was really cheap. Whenever something would break — say, the washing machine — he'd think, I could have the Sears guy fix it, or my son. I learned like that, and I started seeing the whole world that way.

For more Maker Pro news and interviews, visit makezine.com/go/maker-pro, and subscribe to the Maker Pro Newsletter at makercon.com.

DC DENISON is the editor of the *Maker Pro Newsletter*, which covers the intersection of Makers and business. He is the former technology editor of *The Boston Globe*.

Bolt

Power Tips

EVEN THE MOST FUTURISTIC CREATIONS FUNDAMENTALLY RELY ON AN OLD-FASHIONED COMMODITY — ELECTRICITY. Yet for as long as we've been harnessing it, power remains a tricky challenge. Efficiency is essential. One misstep and zap — you fry a beloved bot. The engineers at Arrow Electronics know the pitfalls. Here are three pieces of advice, from three experts, for powering your project to success.

1

LAURA HUGHES is an electrical engineer at Arrow with a background in LED lighting and power supply design, and a notorious tinkerer. She believes that anything can be improved with lights or sprinkles.

THE FIRST PROTECTION AGAINST POWER LOSS IS PLANNING

Don't let circuit protection be an afterthought. Plan your project with it in mind from the beginning — or face some unexpected efficiency hits. Many people default to a simple diode to provide reverse polarity protection, but your favorite old diode could have a forward voltage of up to 1V when passing 1A of current to the circuit — that's an entire watt of loss that is now built into your design. Instead, try something like Fairchild's new FSV family of protection diodes that has a forward voltage as low as 0.3V at 1A.

2

BRIAN KEYSER is an Arrow manager with a background in developing enterprise software. He has always wanted to learn how to manage the devices in his home and is now doing exactly that.

A HIDDEN BENEFIT OF POWER EFFICIENCY: SECURITY

Review the software services you'll run as part of your project. Eliminating unneeded services will conserve power, sure. But it'll also allow you to reduce your "attack surface" (the points where a malicious hacker can enter or extract data). Also consider profiling running services to discover their impact on power consumption. For example, if you plan on performing an operation that requires a large amount of power, such as Bluetooth scanning, experiment with different scan durations and frequencies. Try nonnative hardware. Consider an external device. Try a different operating system.

3

NICK POWERS is Arrow's resident expert in power systems, including batteries. When he isn't working, he's interested in remote control vehicles, backcountry camping, desktop manufacturing, and homebrewing.

LITHIUM'S LURKING DANGERS

A lithium battery can catch fire, explode, or die from overuse. So be prepared when moving from standard primary batteries like alkaline to lithium-based rechargeable ones. Look for cells that already have safeguards to protect against overcurrent, overvoltage and undervoltage, and excessive temperature. Physical protection is also essential: A puncture or severe impact can result in a fire or explosion. Make sure to include a safe method to recharge your batteries, either one built into the system or an external charger that allows the pack to be removed.

Arrow Electronics is the preferred source for everything that Makers need to turn projects into products. To contact Arrow engineers for one-on-one answers to your questions, go to arrow.com/en/design-center.

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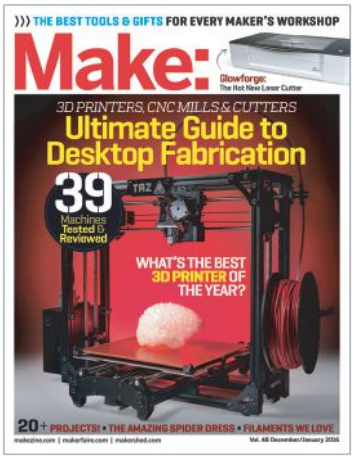
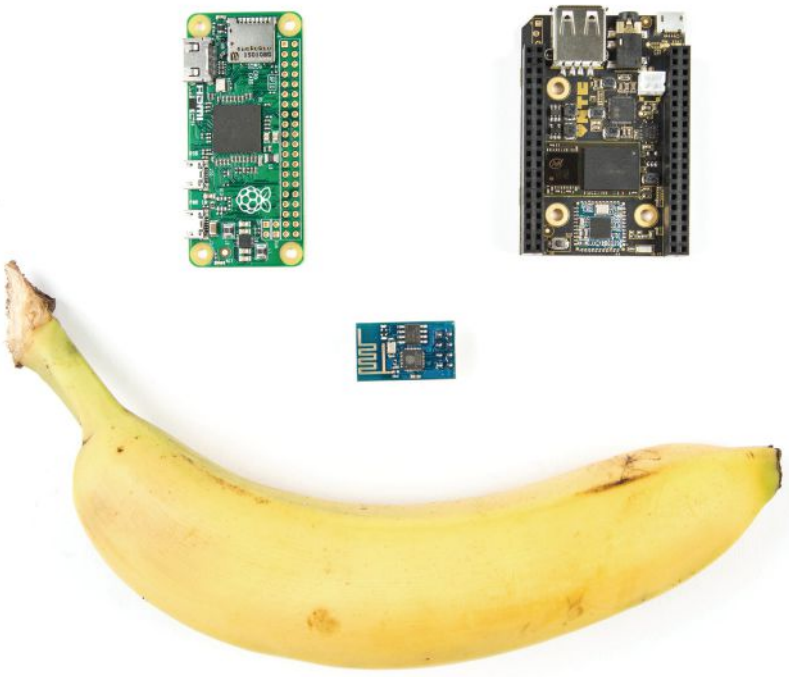


SPECIAL SECTION

SUPER COMPUTERS

BOARD GUIDE 2016

Bang for Your BUCK



What happens when computing is effectively free?

WE'RE ALL FAMILIAR WITH MOORE'S LAW. WE'VE COME TO EXPECT THAT NEXT YEAR EVERYTHING WILL BE FASTER, AND JUST A BIT CHEAPER. While this has held largely true since Gordon Moore predicted it, Intel CEO Brian Krzanich said in 2015 what many have suspected: "Our cadence today is closer to two and a half years than two."

But while some might say we're reaching the limits of our current technology, and that the increase of computing speed will slow dramatically, that doesn't necessarily mean progress is slowing. We're now looking at a more mature technological base. And as technology matures, it becomes cheaper. While computing may not become orders of magnitude faster, or smaller, we'll start caring only whether our computing is "good enough" — that is, it is accessible and performs all the functions needed.

There's still a ton of technology trickling down from the smartphone wars. As 3D Robotics' Chris Anderson says, "when giants battle, we all win."

Sensors such as accelerometers, gyroscopes, magnetometers, and even cameras, are now trivially cheap and readily available. The ubiquity of the ARM processor, used in pretty much every smartphone, has made computing dramatically cheaper, and whole companies such as Adafruit and SparkFun have been built around packaging this technology and making it accessible to Makers.

Capable computing — that "good enough" tech — is now available for just a few dollars. The ESP8266 system on chip, a general use microcontroller with Wi-Fi and — albeit somewhat limited — GPIO can be found in quantity for less than $2. The new C.H.I.P. computer, a direct fallout from the cheap tablet industry, is just $9. And Raspberry Pi's model Zero is like a faster version of the original Pi, but for $5. We're getting to a place where computing is not just cheap, it's effectively free. A $2 microcontroller today leads to a $0.20 microcontroller tomorrow, and eventually to the $0.02 microcontroller.

Eventually we'll see computing, sensors, and wireless networking bundled up in millimeter-scale sensor motes that drift on air currents. The dust around us will become smart. Cheap, capable computing will enable a host of uses that were never possible before. And when computing is disposable, what will you be able to do tomorrow that you couldn't do yesterday?

Hep Svadja

Written by Alasdair Allan

Meet C.H.I.P., the $9 computer

Born from a camera company, Next Thing Co. is the little guy with a big idea

LAST MAY, A LARGELY UNKNOWN NICHE CAMERA COMPANY CREATED AN UPROAR WHEN IT ANNOUNCED IT HAD BUILT A $9 COMPUTER. But as the Kickstarter pledges rolled in — more than $2 million from almost 40,000 backers — it seemed Next Thing Co., co-founded by Dave Rauchwerk, Thomas Deckert, and Gustavo Huber, had made an important contribution, fundamentally altering the cost structure of small computing devices. Other low-cost Linux boards existed before C.H.I.P., but none were less than $10.

As surprising as C.H.I.P. was, it didn't just appear from nowhere. It wasn't even what Next Thing Co. set out to make. It was the offshoot of another product, OTTO, a hackable animated GIF camera based on the Raspberry Pi compute module. TechCrunch proclaimed OTTO as a sure sign "we've reached peak hipster," a headline the team owns with pride. Though the company successfully built and shipped OTTO, it failed to live beyond crowdfunding, not because of snarky headlines, but because it was too expensive to produce beyond fulfilling rewards.

As a result, the team at Next Thing Co. decided to address the high cost of computing. They wanted to build the board that would enable products like OTTO to succeed. "If C.H.I.P. existed when we built OTTO, we would still be a camera company," says Rauchwerk.

Powering C.H.I.P. is a 1Ghz ARMv7 processor from Allwinner with 512MB of RAM and 4GB of storage. That's enough room to comfortably run a customized operating system based on Debian Linux and still have space for applications and source code. Onboard Wi-Fi and Bluetooth low energy, plus the ability to power C.H.I.P. with a LiPo battery, differentiate C.H.I.P. from other low cost platforms such as the Raspberry Pi Zero, which lacks built-in connectivity hardware.

While C.H.I.P. was purpose-built to power hardware creations — the name stands for Computer Hardware Inside Products — the $9 computer is more than just a device for Makers and product designers. C.H.I.P. is a cheap computer: Simply add a monitor, keyboard, and mouse and you can do computer things — programming, gaming, or surfing the web.

This gives C.H.I.P. a bit of a split identity; not only is it an inexpensive computer, it can be easily integrated with other hardware such as sensors and motors. This is thanks to 80 exposed pins on two rows of 40-pin female headers, including 8 general purpose input and output pins along with many others for specific functions.

Since C.H.I.P. became available, users have created a custom software developer kit and forked a C.H.I.P.-specific version of Linux. The Creative Commons-licensed device combines open source software and hardware, allowing designers to build derivative products and customize it to their needs, and making it particularly attractive to those looking to create a product and take it to market.

MEET CHIPPY RUXPIN

Turn to page 42 to see how to use C.H.I.P. to give **Teddy Ruxpin** a brain transplant

Written by David Scheltema

Meet Raspberry Pi Zero,

the $5 single board computer

Spurred by accessibility, the foundation releases its own sub-$10 device

ALREADY SUPPORTED BY A STRONG COMMUNITY, THE RASPBERRY PI FOUNDATION SOLD OUT OF THE INITIAL BATCH OF $5 PI ZEROS — all 20,000 of them — within the first 24 hours of its launch. Zero is a stripped-down version of the Raspberry Pi B+, but don't let that fool you. This is one powerful little board at a price that's hard to beat.

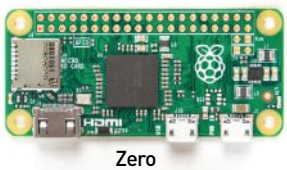
The foundation, a U.K.-based nonprofit with the mission of getting more people familiar and literate with computers, has been a favorite for Makers since 2012, when the first Raspberry Pi came out. Since then, demand and fervor over the boards has not waned; in just three years, the foundation has released six different boards: Pi 1 models A, B, A+, and B+ and the compute module; and the Raspberry Pi 2, Model B. The Zero is the seventh iteration, and much of the design harkens back to the original line of boards, but its price point also represents a renewed initiative by the foundation to get the board in more hands.

The first thing to notice about Zero is that it is the smallest Raspberry Pi ever, just 30mm×65mm and only 6mm tall. Its size lets you fit a tiny computer inside even the most compact project. To achieve that, the large, bulky HDMI and standard size USB ports are replaced with mini HDMI and two micro USB ports, respectively. Absent are Ethernet, TRRS audio out, and composite video — though that can be added later by soldering two pins to pads labeled "TV." Also missing, without the potential to breakout from unpopulated pads, are the CSI and DSI plastic ribbon connectors, which are used on other Pis to interface camera and touchscreen display.

Due to the shrunken form of the connectors, Zero requires two specialized USB cables — a micro USB to standard USB and a USB on-the-go (OTG) cable — as well as a mini HDMI to standard HDMI cable. That's not a huge detractor from using the Pi, but it is something to be aware of when ordering the board. Make sure to get these accessories.

What the Pi Zero retains is the Broadcom BCM2835, which is the same processor as in all previous Raspberry Pi 1 boards (every board except the Pi 2, Model B). The processor clock speed on Zero is bumped up to 1GHz from its first-gen cousins, which operate at 700MHz. With 512MB of RAM, there is plenty of room for running most applications and computing tasks without lag. Multitasking with the Pi Zero is not as snappy as it is with Pi 2, Model B, but that's because the Zero doesn't have a quadcore architecture. Provided that spending money on cabling isn't an issue, then the Pi Zero is a great board for the price.

B+



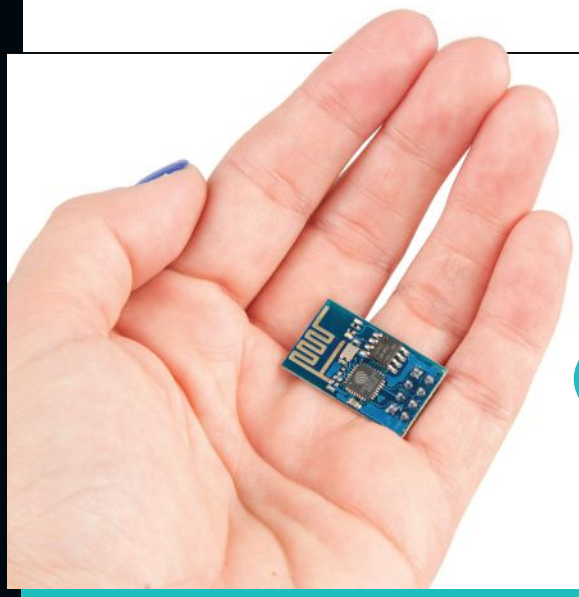
Zero

Kiwi

Create your own Pi Zero Pirate Radio Throwies at makezine.com/go/pi-zero-radio-throwies.

Hep Svadja

Written by David Scheltema



Meet ESP8266,
the $3 microcontroller

Some clever programming took the Wi-Fi accessory to new frontiers

THE DAY BEFORE MAKERS AROUND THE WORLD CELEBRATED ARDUINO DAY ON MARCH 28, 2015, major news quietly hit the ESP8266 forums. A post by Richard Sloan declared that he and Ivan Grokhotkov had successfully hacked ESP8266 support into the Arduino IDE. For those following the forum this announcement was a big deal; for everyone else, it would be a week or two before Sloan and Grokhotkov's work resonated: The ESP8266, until then used only as a Wi-Fi accessory for Arduinos and other microcontrollers, could be programmed directly as a standalone board.

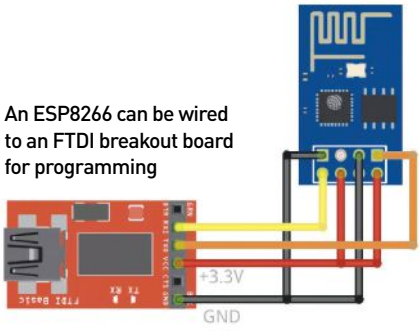
Available for $3-$7 (even less in quantity), the ESP8266 was originally designed as a Wi-Fi communication expansion board. Prior to Sloan and Grokhotkov's software, users had already noted that it could be programmed using basic modem instructions known as AT-commands. Microcontrollers easily parse AT commands, but they are not fun for humans to work with. Developing an interface with more user-friendly programming language, such as the C/C++ familiar to Arduino sketch programmers, is what made the ESP8266 vastly more popular.

The ESP8266 lacks an FTDI chip, which typically allows a board to have an external communication port like USB, so you have to use a separate hardware interface such as the FTDI Friend to program it. Fortunately, instructions are now easily available to set everything up properly.

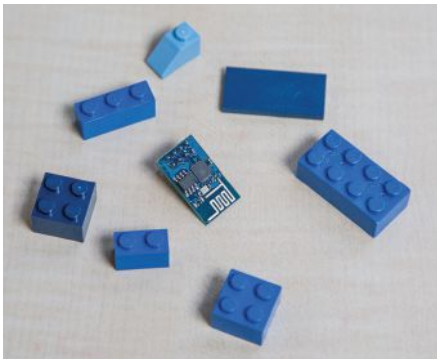
Thanks to these software improvements, it's easier than ever for people to create projects with the ESP8266 at the center of their design. Internet of Things projects, such as data logging stations or panic buttons, are the most common (See pages 40-41). With each project, small Arduino sketches run directly on the ESP8266 and shuttle data between the input pins and the Wi-Fi connection.

Espressif Systems, the company that manufactures the ESP8266, has been so receptive to feedback about their product and how it is being used that their next board, the ESP32, is integrating much of the community's suggestions into the design. Now entering a beta phase, the new board is planned to have faster Wi-Fi, onboard Bluetooth, and two processors to handle the Wi-Fi and code execution separately.

Whether it's adding Wi-Fi to a board that lacks it (such as the Pi Zero), or simply running the ESP8266 in a standalone mode, the board is certainly worth experimenting with, and cheap enough to buy a bunch.



An ESP8266 can be wired to an FTDI breakout board for programming



If you're not sure how to get started with the ESP8266, **check out our guide** to building an Arduino sketch at makezine.com/go/program-esp8266.

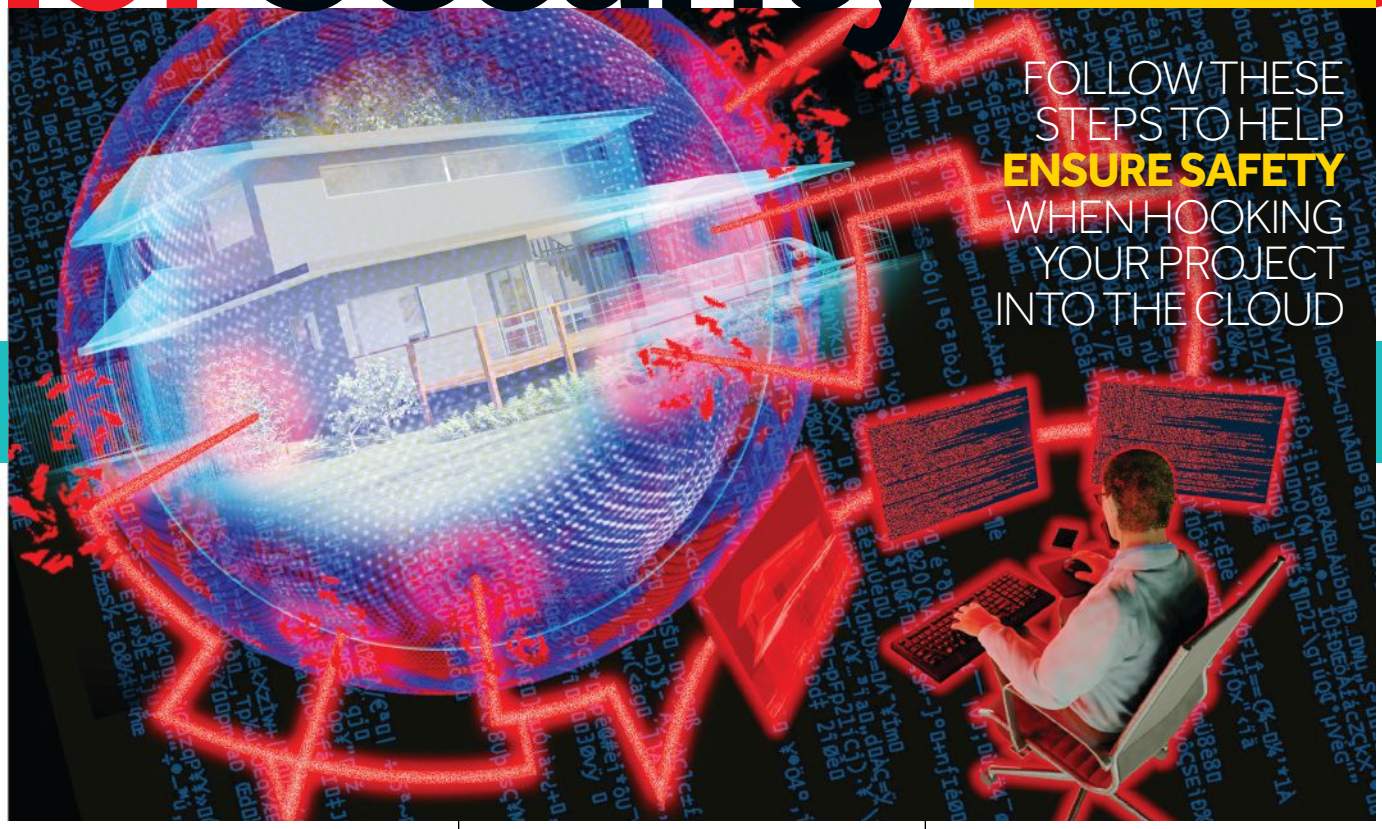
Learn how to use an ESP to collect Reddit's Shower Thoughts in "A Flood of Thoughts" on page 68

Alasdair Allan, Hep Svadja

Written by David Scheltema

IoT Security

BRENT CHAPMAN is an active duty Cyber Warfare officer in the U.S. Army and researcher at the Army Cyber Institute at West Point. When not in uniform, you can find him in his wood shop or basement tinkering and building.



FOLLOW THESE STEPS TO HELP **ENSURE SAFETY** WHEN HOOKING YOUR PROJECT INTO THE CLOUD

THE EMERGENCE OF INTERNET OF THINGS (IOT) DEVICES HAS BEEN A BOON FOR HOBBYISTS AND MAKERS, with an array of components now available for easy integration into our lives. However, as we put more faith in these connected devices to give us visibility over our homes, families, and personal property, we must take extra care to protect these networks and maintain the confidentiality, integrity, and availability of the data that flows through them. Quickly wiring an ESP8266 — or one of many available Arduino or Raspberry Pi shields — to the internet will get your project online, but could also expose you to vulnerabilities.

Here are four areas to consider for safety when integrating an IoT device into your system. Using all of these mechanisms together is called *defense-in-depth*. Should an attack defeat one mechanism, the other solutions may provide the necessary protections to maintain system availability.

HOME NETWORK SECURITY

- Require strong passwords. These are incredibly effective against an attack.
- Ensure that connected devices support newer security protocols like WPA2. Some older protection schemes such as WEP are known to have major security flaws.
- Minimize the number of open ports to the rest of the internet. Disable unnecessary services like Telnet and UPnP.
- Just like the access points, routers, or servers that they connect to, IoT devices should not be physically exposed to unauthorized access.

IOT DEVICE SECURITY

- Update to the latest firmware or version as soon as they are made available.
- Change default passwords on devices.
- Ensure that the web interface provides account lockout against an attacker attempting to "brute force" the system.

ENCRYPT. ENCRYPT. ENCRYPT.

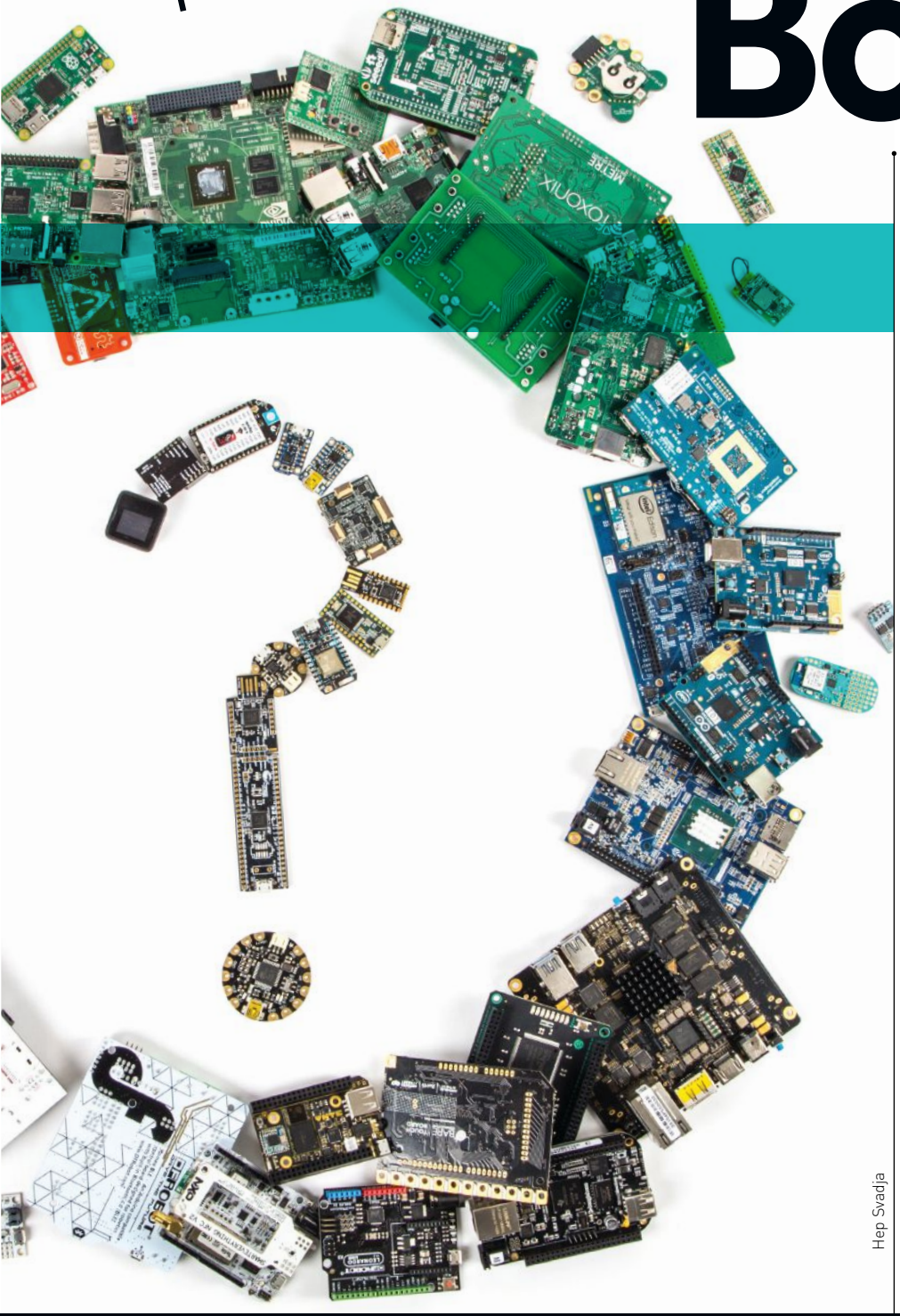
- IoT devices have the potential to transmit a lot of sensitive data like passwords, personal information, photos, and videos. Encryption between devices helps protect the data while in transit across networks. Use well-known standards that have been vetted by the security community.

THE CLOUD AND PRIVACY

- Does the data need to be stored elsewhere? If not, disable cloud storage. If so, use smart practices such as two-factor authentication and strong passwords.
- Carefully review the type and amount of data that's collected by the devices. The information collected may be excessive or not protected properly. Opt out of data collection or enable anonymized collection where available. Understand that many "free" services are often paid for with user data.

Written by Brent Chapman | Illustrated by Peter Bollinger

HOW TO Choose A Board



Hep Svadja

FIGURING OUT HOW TO SELECT THE RIGHT DEVELOPMENT BOARD IS A KEY SKILL for all electronics makers. Despite their various functions and options, development boards and cheap computers are ultimately just specialized tools created to accomplish computational tasks, so choosing them should be guided by the tasks you're trying to complete.

On the surface, the decision seems fairly easy to resolve: Pick a popular board with a large user community, one that has robust documentation, and that won't cost more than a quarter of your project budget. That approach would probably be fine if there were only a handful of boards available. But the reality today is that there are hundreds — if not thousands — of devices to select from. Plus, these devices are not only getting cheaper, they are becoming more specialized in design and functionality.

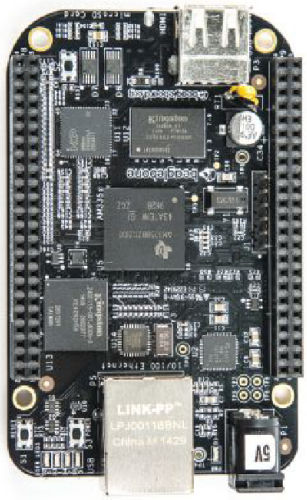
When choosing your board, avoid getting bogged down in the specifications — rather, begin by thinking in broad terms about what you want your project to accomplish. This can be challenging. Finding a good board to learn to code on or blink a couple of LEDs is fairly easy, but determining which device to use for a robot that balances on a large ball entails a more complex set of design requirements. Knowing what features you want from your board will get you farther than selecting a platform just because it has an octocore processor or SATA ports built-in.

Choosing a board in this manner will enable you to quickly eliminate some options. Use the following guides to help narrow the field based on the category of your project, then find recommendations for boards that should give you a smooth start.

How to Choose a Board: Robotics

Building a robot is a rite of passage for many Makers. And as soon as you build one, you'll want to build another that is faster and more feature-packed.

With the demanding requirements of robotics it's important to find a board that excels at real time processing and has plenty of input and output pins to wire up accessory hardware. Typically this means a board that runs Linux, which supports the Robot Operating System. These three boards pack a lot of processing punch, perfect for higher-end robotics projects.



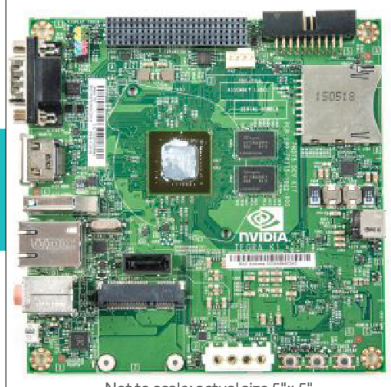
Actual size

BEAGLEBONE BLACK

By BeagleBoard | $55

This relatively inexpensive single board computer operates at 1GHz with 512MB of RAM, and has 4GBs of built-in eMMC flash storage.

Augmenting the clock speed are two onboard microcontrollers, called programmable realtime units (PRUs). The PRUs are within the silicon of the main processor and can be programmed to offload realtime computation for things like robotics motor control or high-speed pin toggling used in lighting control. Each operates at 200MHz, and two large rails of GPIO provide ample wiring options. Best of all, the board is open source hardware — meaning you can adapt the design to your own custom needs.



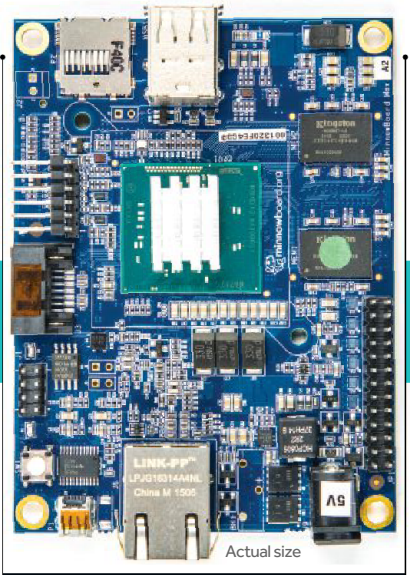
Not to scale; actual size 5"× 5"

NVIDIA JETSON TK1

By Nvidia | $192

The graphics processor onboard this power-packed 2.32GHz quadcore development board, with 2GB of RAM and 16GB of eMMC flash storage, is great for computer vision tasks on autonomous robotics. The powerful GPU, with an astonishing 192 CUDA cores (Compute Unified Device Architecture), allows non-graphics software tasks to be offloaded onto the GPU.

Connecting accessories to TK1 is a breeze, since there are so many ports: USB 3.0 and 2.0, a DB9 RS232 serial port, miniPCI-e, SATA, JTAG, gigabit Ethernet, and that's before you look at the 25-pin 2mm-pitch expansion headers with pins for I2C and even two CSI camera interfaces.



Actual size

MINNOWBOARD MAX

By MinnowBoard | $145

This 2.9"x3.9", dual core 64-bit Intel Atom-based system operates at 1.33GHz, with 2GB of DDR3 RAM. Unlike the Beagle or TK1, MinnowBoard Max is x86 architecture, not ARM, but still runs a familiar Linux operating system.

The open hardware Max offers low-speed buses such as SPI, I2C, I2S audio, two UARTS, and 8 buffered GPIO (two configurable for PWM), all accessible on a 26-pin male header. Its high-speed buses for SATA2, PCIe, and more are accessible from a 60-pin high-density connector. USB 2.0, 3.0, and gigabit Ethernet are also standard, so connecting Max to fancy USB accessories is a snap.

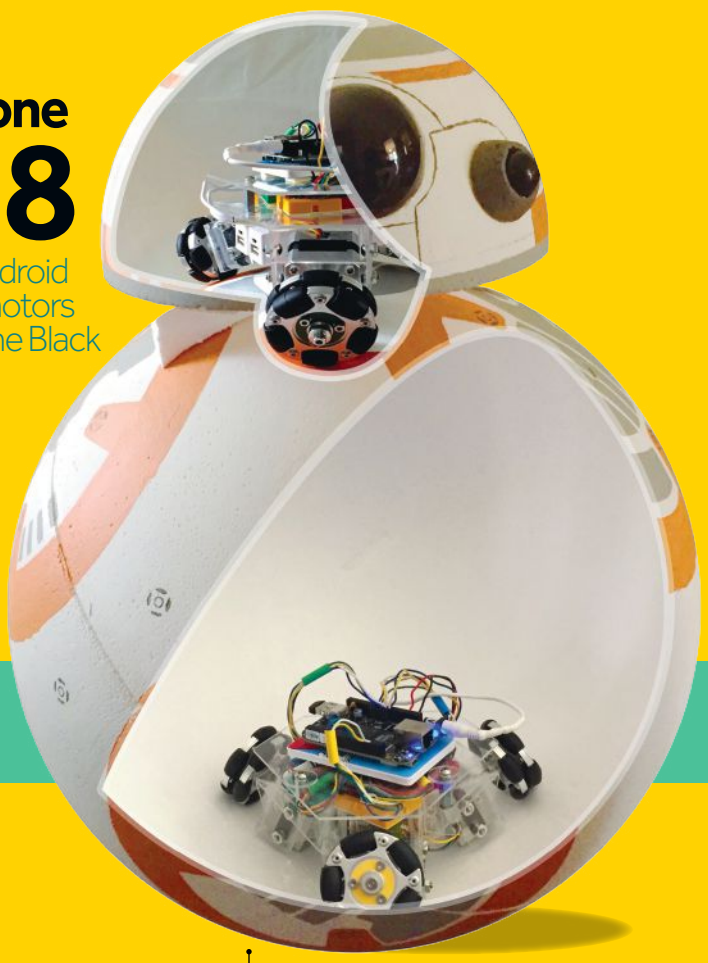
James Burke, Hep Svadja

Written by David Scheltema

Project: BeagleBone BB-8

Build your own droid with stepper motors and BeagleBone Black

Written by Eric Boehlke



ERIC BOEHLKE is a high school senior who loves to design, build, and program robots. He has been making them for 8 years. BB-8 is his first non-Lego NXT robot.

Materials

- **BeagleBone Black, Rev C, 4GB, (2)**
- **Wi-Fi adapter, USB, D-Link DWA-121 (2)**
- **Breakout board, 10-DOF IMU (2)** Adafruit.com
- **Motor driver breakout board, TB6612, 1.2A (6)** Adafruit.com
- **Mini breadboard (8)**
- **Stepper motor, NEMA-17 size 200 steps/rev 12V 350mA, (6)**
- **Aluminum mounting hub, 5mm, RB-Nex-98 (6)** RobotShop.com
- **Aluminum omni wheel, 60mm, RB-Nex-75 (6)** RobotShop.com
- **Acrylic sheet, clear .093"×11"×14" (2)**
- **Nuts and bolts**
- **Polystyrene balls, in 2 hollow halves, 50cm and 30cm** Craftmill.co.uk
- **Acrylic paint, white, orange, and gray**
- **Super thick gesso** for acrylic paints
- **Backup battery pack, rechargeable, 2500 mAh (2)**

Tools

- **Bandsaw**
- **Drill**
- **Drill bits 5/32", 3/16", 3/8"**
- **Hole saw, 1"**
- **Loctite 2 stage plastics bonder**
- **Paintbrushes**
- **Gesso brush, 3"**
- **Screwdriver set, hex**
- **Glue stick**
- **Foam tape, double-sided**

USING TWO SEPARATE OMNI WHEEL ROBOTS, EACH CONNECTED TO A BEAGLEBONE BLACK that controls their numerous advanced functions, Eric Boehlke designed a full-sized animated replica of the BB-8 droid from *Star Wars: The Force Awakens*. The build is a crash course in teaching robots how to balance using a combination of sensors. Here are his notes; see details at makezine.com/go/beagle-bb8.

• • •

PROGRAMMING

I used Python to program the two BeagleBone Blacks, and chose stepper motors because they allow for precise movement and hold their position when stationary. A 10-axis inertial measurement unit determines the robot's position. BB-8 can take direction via Wi-Fi or follow a pre-programmed path.

HOW IT WORKS

A balancing robot needs at least two sensors to help it know when it is falling: an accelerometer, and a gyroscope. The accelerometer measures the forces acting on the robot including the robot's movement. The gyroscope precisely measures the angular velocity of the robot, but not pitch and roll.

For a robot to balance well the values from the accelerometer and gyroscope have to be combined. A Kalman filter takes the gyroscope and accelerometer values and calculates the amount of trust each one deserves, and can change the amount of trust while running. Once the pitch and roll are calculated by the Kalman filter, the robot takes the arctangent of the two values to find the driving angle.

The robot also needs to know how fast to go. The best way to calculate the speed is to use a PID (Proportional Integral Derivative) controller, which lets the robot act in proportion to the distance from the center while keeping it from going too far, and allowing the robot to react quickly to any sudden changes.

The driving angle and the driving speed are given to the robot which can calculate how fast each of the omni wheels should turn to achieve the desired direction and speed. The motor controller program turns the speed of the wheels into electrical signals that are given to the motor controller breakout boards to turn the motor.

To move the wheels, I used pulse-width modulation (PWM) to control the amount of power going to each coil. Using sine and cosine to determine the correct values, I was able to implement smooth motion with microsteps.

GOING FURTHER

I plan on refining the PID controller to improve the responsiveness. I also want to have the head be able to turn and nod while balancing. This will allow BB-8 to communicate with simple actions.

Eric Boehlke

Time Required: 2–3 Weeks | Cost: $700–$800

How to Choose a Board:

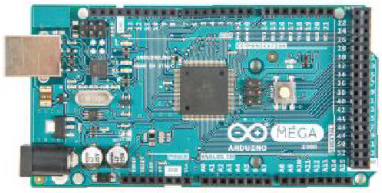
LIGHT AND SOUND

The largest factor to consider when tackling a light or sound project is the scale: If you only need to drive a few elements, you can get away with using a small number of I/O pins, but driving larger displays at high speeds will likely require the use of more I/O. There are several board options that can help simplify this problem for large and small projects alike. But remember, the boards usually just handle the control side of the installation — most large projects also require relays, MOSFETs, and/or amplifiers to deliver the power to the various lights and speakers.

ARDUINO MEGA 2560

By Arduino | $46

The Arduino Mega is the powerhouse of the microcontroller-based Arduino line. With 54 digital I/O pins and 16 analog inputs, the Mega offers enough inputs and outputs to control even the biggest audio-visual projects (Yep, even concert light shows!). It also has four UARTs (compared to the Arduino Uno's one), so you can easily link up with multiple other devices and create something truly massive.



Not to scale; actual size 4"× 2.1"

TEENSY 3.2

By PJRC | $20

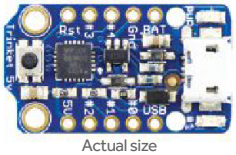
While it looks small, the Teensy can perform some pretty impressive feats. In addition to its 34 digital I/O pins, there are adaptors available for audio output, LED matrices, and more. It's also Arduino compatible, so after downloading the driver, you can program it using the Arduino IDE you know and love.

Actual size

TRINKET

By Adafruit Industries | $7

Not all projects have to be massive, and sometimes you just want a cheap, simple, small solution. The Trinket checks all of those boxes, and despite its meager three I/O pins, it's a great choice for driving just a few LEDs, or controlling whole LED strips. It can be programmed via the Arduino IDE, is compatible with many basic Arduino libraries, and it's small enough to fit into just about any project.



Actual size

James Burke, Hep Svadja, Dan Royer

Project:
LED Jumbotron

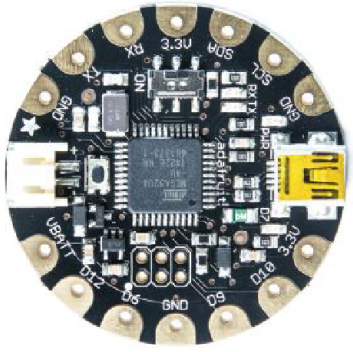
Because who doesn't want a giant LED video screen? Take the Teensy microcontroller's Arduino programmability, add custom RGB LED driver boards, and anyone can build a wall-sized video display with 2,304 blazing-bright, full-color pixels. Scale it up even bigger and you can compete with MLB ballparks and Times Square. See the complete how-to instructions on page 62.

Written by Jordan Bunker

How to Choose a Board:

WEARABLES

Making wearable electronics projects can be a bit tricky. In addition to devising a system for attaching and connecting components to your apparel or accessories, you should consider the actual size of the board and its power and computing requirements. Ideally, you want to use a small, low-profile board that easily connects to a battery for portability, and that can be sewn into a garment. Thankfully, there are microcontroller boards and single board computers that are designed with all of these things in mind, and with plenty of computing power to boot. These three are solid options to get most projects up and running.

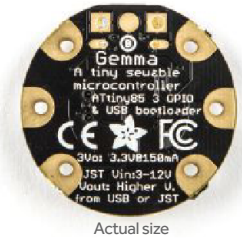


Actual size

FLORA

By Adafruit Industries | $20

The Flora was developed specifically for wearables projects, and has 14 sewing tap pads for connecting conductive thread to your components. It features an onboard battery connector and a 2A power FET, making it easy to add portable power (and plenty of it). With so much power, the Flora is perfect for controlling large numbers of LEDs, and it can even drive up to 50 NeoPixel addressable LEDs straight from the onboard supply.

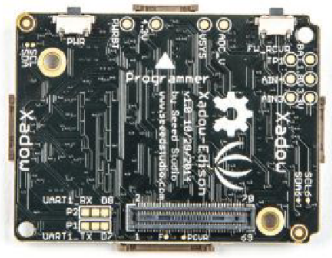


Actual size

GEMMA

By Adafruit Industries | $10

You might think of the Gemma as a "lite" version of the Flora. It has just 3 digital I/O pads, but at 1.1" in diameter, it's incredibly tiny. Like the Flora, it has an onboard battery connector, and is programmable via the Arduino IDE. While it may seem that its minimal I/O count limits its potential, many projects don't require lots of I/O pins, making the Gemma the ideal choice for simple wearables designs.



Actual size

XADOW-EDISON

By Seeed Studio | $130 (Kit with accessories; Intel Edison not included)

Based on the Intel Edison single-board-computer, the Xadow-Edison board puts the Intel Edison in a convenient and powerful wearable package. There are numerous actuator, sensor, and interface modules that connect via flexible flat cables, making it easy to design and build your own custom wearable project as quickly as possible. With the computational capability of a single-board-computer, the Xadow-Edison board allows you to bring even the most complicated ideas to fruition.

James Burke, Hep Svadja

John de Cristofaro

Project: **Sparkle Skirt**

Use a Flora board to create this LED-illuminated skirt that sparkles in response to accelerometer and compass sensor data. This project uses conductive thread instead of soldering and can be adapted for many different articles of clothing, including belts, pants, or a hat. Find the complete project at makezine.com/go/led-sparkle-skirt; this and more illustrated, step-by-step wearable projects can be found in the book *Getting Started with Adafruit FLORA*, published by Maker Media.

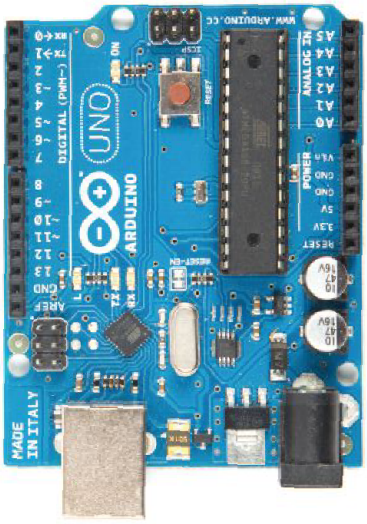
Written by Jordan Bunker

How to Choose a Board:

Education

Development boards provide a self-contained computing environment — a very affordable sandbox great for learning how to program. When buying a starter board, be aware that there are two general types: those that run an operating system and those that don't. Either will work, but if you're new to coding, a system without an OS might be easier, as they typically only support one language.

Whatever you choose, the key is to dive in and start coding. Here are three boards we think are perfect for the task.

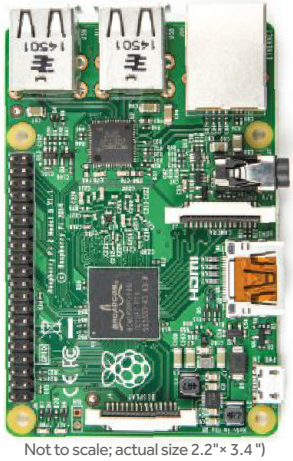


Not to scale; actual size 2.1"× 2.7")

ARDUINO UNO

By Arduino (Genuino internationally) | $25, $75 for a *Make:* Getting Started Kit

Designed originally for non-technical users, the Arduino Uno is programmed using a very readable C/C++ syntax. With a consistent, cross-platform development environment, writing code for Arduino quickly becomes a familiar experience regardless of your host operating system. The Uno can quickly be wired up to accessory boards called shields to expand functionality without having to solder. And since Arduino boards have been around since 2005, it's easy to find good projects, tutorials, and a worldwide community of people ready to help.



Not to scale; actual size 2.2"× 3.4 ")

RASPBERRY PI 2, MODEL B

By the Raspberry Pi Foundation | $40, $129 for a *Make:* Getting Started Kit

Using the Pi is just like operating a computer. Connect peripherals (keyboard, mouse, and monitor), power on the device, and you're basically running a desktop computer from the '90s. The Pi runs Raspbian Linux, which offers a graphical interface and since Linux has hundreds of development environments

Not to scale; actual size 5.13"× 5.2"

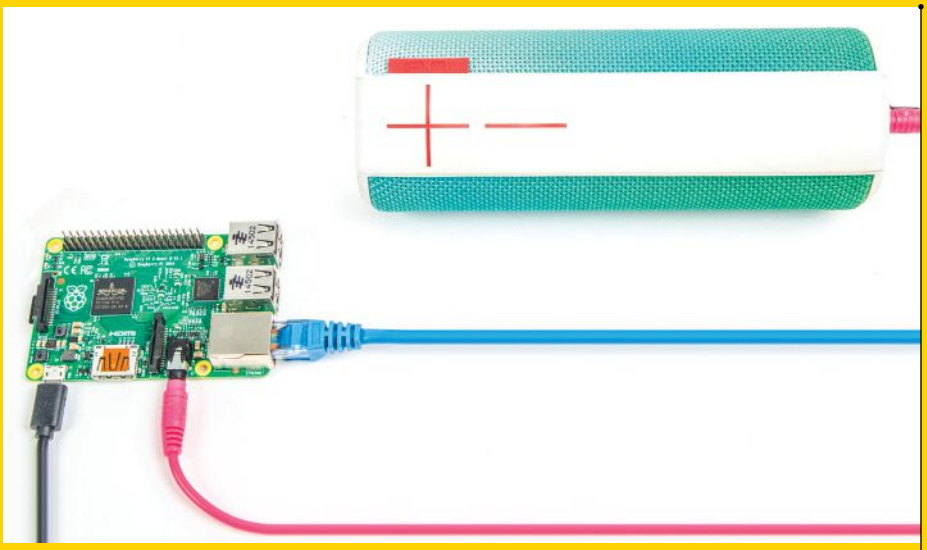
KINOMA CREATE

By Kinoma | $150

The Kinoma Create is a JavaScript (or ECMAScript for the purists) dream. This board offers 16 input and output pins hidden behind a front panel, and 50 more in the rear battery bay. Once connected over built-in Wi-Fi, configurable from its touchscreen display, the Create accesses the Kinoma git repository with hundreds of project examples. To program you just download a customized Eclipse IDE, which offers simulation, debugging, and uploading code to Create trivial task. Preloaded with JavaScript 6, the Create is ideal for a web developer looking to get started programming on development boards rather than websites.

James Burke, Hep Svadja

Written by David Scheltema



ADAM BURKEPILE is a full-time software consultant and independent iOS developer. If he isn't at the computer, he's probably getting punched in the face at Krav Maga.

Materials

- **Raspberry Pi single-board computer** such as the Pi 2, Model B, item #MKRPI8 at the Maker Shed, makershed.com
- **SD Card, 4GB or bigger** This is the storage for the project and acts as the hard drive for the Raspberry Pi. Get a Pi and 8GB SD card together in our deluxe Raspberry Pi Getting Started Kit, Maker Shed #MSRPIK7.
- **Micro-USB cable** to power the Pi. Also comes in our Getting Started Kit.
- **Ethernet cable** The Pi doesn't have Wi-Fi built in, so you'll use the wired connection for this project. You could also substitute at Wi-Fi add-on board.
- **Any set of powered speakers with a mini audio cable** so you can hear your AirPlayed audio

Tools

- **Computer, Mac OS X or Linux, with memory card reader** to load the OS onto the SD Card, and to connect to your Raspberry Pi via SSH
- **iPhone or iPad** to AirPlay your audio from, and to run the demo app

Project: **Raspberry Pi AirPlay Receiver**

Stream your tunes wirelessly while learning how your Pi works

Written by Adam Burkepile, raywenderlich.com

HAVE YOU BALKED AT BUYING PRICEY AIRPLAY SPEAKERS TO WIRELESSLY STREAM YOUR MUSIC? With an inexpensive Raspberry Pi computer you can turn any powered speakers you already own into AirPlay speakers. (And this project gets even more affordable with the $5 new Raspberry Pi Zero and a cheap Wi-Fi card!)

And while there are ready-to-go AirPlay software options for your Pi (like Volumio), you'll learn a lot about how the Pi works by following the steps of this project to make your own. Here's the overview; for more details, visit the project page at makezine.com/go/raspberry-pi-airplay-speakers.

1. Download and install the Raspbian OS onto your SD card using your laptop.

2. Install the card into your Pi. Connect USB for power and Ethernet for data.

3. Use the iPhone app Fing to find your Pi's IP address (Figure A).Then use SSH to connect to the Pi remotely from your laptop — use a Terminal window to log in by typing its IP number, such as:

```
ssh pi@192.168.1.10
```

(replace with your Pi's IP address)

4. Create space on the partition by running the command `sudo raspi-config` and selecting the `expand_rootfs` option. Reboot.

5. Update packages to get the latest versions, change the default audio output to your Pi's mini jack, then download and install a series of prerequisite files using the following command:

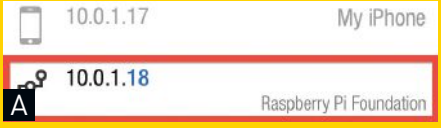
```
sudo apt-get install git libao-dev libssl-dev libcrypt-openssl-rsa-perl libio-socket-inet6-perl libwww-perl avahi-utils libmodule-build-perl
```

6. Clone the Github repository of Perl Net-SDP onto your Pi. This helps the Pi communicate with the AirPlay protocol. Still in SSH, run:

```
git clone https://github.com/njh/perl-net-sdp.git perl-net-sdp
```

7. Now compile and install Perl Net-SDP:

```
cd perl-net-sdp
perl Build.PL
sudo ./Build
sudo ./Build test
sudo ./Build install
cd ..
```



8. Install and run Shairport:

```
git clone https://github.com/hendrikw82/shairport.git
cd shairport make
```

9. Finally, run the command to start Shairport and name your AirPlay receiver. In this case, we're naming it RayPi:

```
./shairport.pl -a RayPi
```

All set! Now if you open any audio or music app on your iOS device or open iTunes on your Mac, you'll see your Pi on the list of AirPlay devices (Figure B)!

Take it further by adding a daemon script to boot Shairport automatically whenever you start your Pi — learn how at makezine.com/go/raspberry-pi-airplay-speakers.

Hep Svadja

Time Required: 60–90 Minutes | **Cost:** $20–$50

How to Choose a Board:

Home Automation

Wiring your home with sensors to monitor conditions or actuate devices is fun, but it's no small task. A good approach is to divide the project into two parts: one central processing device, and multiple remote nodes for sensing. Both ends of the system require great connectivity, easy remote code deployment, and low power draw.

Since most homes aren't wired with Ethernet cables, boards with built-in Wi-Fi are almost a prerequisite here. And having a handful of available input and outputs is nice too.

Actual size

PHOTON

By Particle | $19, $49 for an IFTTT-Ready Internet Button Kit

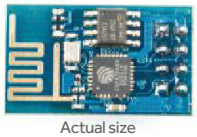
The Photon is designed for the Internet of Things, and Particle runs its own cloud infrastructure to support its ecosystem of devices. Configuring the Photon to connect to the cloud is a breeze. Download the Particle smartphone app (Android or iPhone), connect the board to your network, and start coding using Particle's web-based development environment. Those familiar with Arduino will find that the tiny board offers both analog and digital I/O, mimicking the Arduino Uno.

Actual size

WIPY

By WiPy | $32

WiPy is an excellent device for those who know Python (or want to learn) and it's designed to easily connect to home networks. The board doesn't draw much power while crunching numbers — only about 14mA — and can drop into a super low-power hibernation state drawing just 5µA. With up to 25 GPIO pins, the WiPy can handle a good number of environmental sensors and actuators.



Actual size

ESP8266

By Expressif | $3–$7

The ESP8266 is one of the cheapest standalone Wi-Fi boards you can buy. Designed as a wireless expansion board for microcontrollers, users have worked to enable the Arduino IDE to support ESP8266 programming. Deploying code to the chip is now as straightforward as writing an Arduino sketch and hitting Upload. You'll need an FTDI Friend to directly program the ESP8266, or you can use a specialized version of the ESP8266 with a built-in FTDI chip from SparkFun (ESP8266 Thing, $16) or Adafruit (Huzzah ESP8266 Breakout, $10).

James Burke, Hep Svadja

Written by David Scheltema

Hep Svadja

Project: **Smartphone Garage Door Opener**

Ditch the clunky clickers, using an affordable Wi-Fi microcontroller

Written by Tyler Winegarner

TYLER WINEGARNER is a video producer for *Make:*, a tinkerer, motorcyclist, and gamer. Reads the comments. Uses tools, tells stories. Probably a human. Tweets @photoresistor.

Materials

- **Particle Photon microcontroller board with Wi-Fi** Maker Shed item #MKSPK01, makershed.com
- **Project enclosure** about 2"×2"×5"
- **Relay module, 2-channel, 5V 15-20mA driver current equipped with high-current relays, AC 250V 10A, DC 30V 10A** such as SainSmart #20-018-100-CMS or Amazon #B00E0NTPP4
- **Jumper wires, female-to-male** Maker Shed #MKKN5
- **Mini breadboard** Maker Shed #MKKN1
- **Hookup wire, 22AWG** Maker Shed #MKEE3
- **Double-sided foam tape**
- **Hook-and-loop tape, adhesive backed** aka velcro
- **USB AC adapter, 5V 1A** aka wall wart or wall charger
- **USB cable, standard-A to micro-B**

Tools

- **Smartphone, Android or iOS**
- **Rotary tool with cutting wheel** such as a Dremel
- **Screwdrivers, Phillips and flat head**
- **Wire cutters and strippers**
- **Computer with internet connection**

OLD GARAGE DOOR OPENERS HAVE BULKY REMOTES, but I wanted something small, inexpensive, and secure that I could use in multiple vehicles.

Then I stumbled on Blynk, a cloud platform that lets you control all kinds of boards with a phone app. I used it with the Wi-Fi-enabled Particle Photon to build my system.

1. MODIFY THE ENCLOSURE

Cut a ½" hole on each end for wiring.

2. MOUNT THE BOARDS

Tape the relay breakout board and mini breadboard inside the enclosure's lid. Insert the Particle Photon into the breadboard, and connect the relay: GND to GND (violet wire), IN1 to D0 (yellow wire), IN2 to D3 (purple wire), VCC to 3V3 (red wire) (Figure A).

3. GET BLYNK ON YOUR PHONE

Install Blynk and create an account. The app connects your phone and microcontroller by sharing an authentication token between the two. Then it's easy to control the GPIO pins on your board from your phone!

4. CONFIGURE A BLYNK PROGRAM

In Blynk, tap on Create New Project, give it a name, and select Particle Photon from the hardware model field. Go to the Auth Token field and hit the E-mail button to send the token to yourself. Finally, tap the Create Project button to save your configuration.

Tap the screen, click the Button widget, change the Pin assignment to D0, and ensure that momentary (Push) is toggled on. Name your button ("Garage") and save.

5. PROGRAM YOUR PARTICLE

Open the Particle Build IDE (build.particle.io/build). Click Create New App and give it a name. Click the bookmark icon to open the library browser, then scroll down to Community Libraries, input `Blynk` in the search field, and click on the Blynk result.

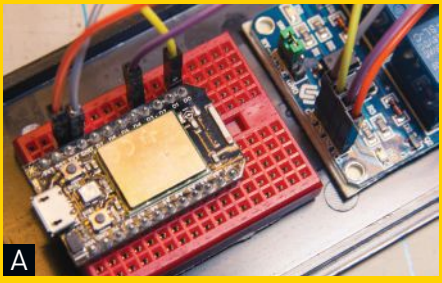
Click the button that says Include In App. This simply adds the line `#include "blynk/blynk.h"` to your sketch. Grab our sample code from makezine.com/go/blynk-garage and paste it into the sketch below the `include` line. Finally, replace `authtoken` with your custom auth token. Now click the lightning bolt icon to flash the code onto the Particle Photon.

6. INSTALL THE PROJECT

Cut a short length of wire and bridge the 2 relays on their common pins (Figure B).

Turn off the power to your garage opener. Connect a red wire between the relay's far left terminal and the opener's antenna terminal. Connect a black wire between the relay's far right terminal and the opener's ground wire. That's it! Mount your project box on the garage opener using velcro tape, then plug your Photon into wall-wart power.

Now whenever you roll up to your garage door, just hit the Garage button in the Blynk app and you're in!


A


B

Tyler Winegarner

Time Required: 1–2 Hours | **Cost:** $40–$50

GIVE TEDDY A **C.H.I.P. BRAIN TRANSPLANT** AND HE'LL SPEAK ANYTHING YOU TYPE OR TWEET—WITH SYNCHRONIZED MOUTH AND EYE MOVEMENTS

Chippy Ruxpin

Hep Svadja

Time Required: 3–4 Hours | **Cost:** $40–$60

Written by Andrew Langley

IT WAS DECEMBER OF 1985 WHEN I WATCHED IN HORROR AS MY FATHER BEGAN RIPPING APART MY FAVORITE TOY. Teddy Ruxpin, for those unfamiliar, was an animatronic storytelling teddy bear that was a close friend to many children of my generation. When an official Teddy Ruxpin cassette tape was inserted into his back, he would spring magically to life, blinking his eyes and moving his mouth to speak in a gentle, non-threatening voice. My dad was certainly sick of hearing Teddy sing songs and regale me with tales of high adventure, so he had decided to add a custom headphone jack and spare his sanity.

While I feared for my animatronic friend as he went on the operating table, I was fascinated as my dad explained the inner workings of the bear. The audio cassette tape contained two tracks: one reserved for the voices and music, and the other containing audio frequencies that told the circuits how to move the mouth and eyes in perfect synchronization. It was all pre-programmed. There was no magic involved.

More than 30 years later, I found myself at Next Thing Co., brainstorming ideas of entertaining things we could make with C.H.I.P., the world's first $9 computer.

Remembering back to that cold December afternoon, I suggested we hack a Teddy Ruxpin so we could control him over Wi-Fi and make him say whatever we wanted. Maybe read us tweets. Why not?

Thus, the goals of the project were established: C.H.I.P. would log on to your existing Wi-Fi network and present a custom web page with a text box. Users would type what they want the bear to say, or tell him to read Twitter messages based on specified search terms. A text-to-speech engine would be utilized to read the results out loud and automatically move the mouth to perfectly match the voice. All of this would be powered by a 3.7V LiPo battery, using C.H.I.P.'s built-in charging circuit through a micro USB connection.

1. SURGERY

The first step was opening up Teddy Ruxpin to see how exactly we could use C.H.I.P. to control the motors. Attached to his original circuit board were 3 connectors powering 3 different motors: for the lower jaw, upper jaw, and eyes (Figure A). Each connector contained 5 wires, 2 of great interest: one that moves the motor forward, and one for reverse (Figure B). Perfect for our needs.

2. BRIDGING THE MOTOR GAP

The motors for the upper and lower jaws are wired independently from one another, so in the interest of synchronizing them together, you'll need to connect them.

An H-bridge circuit works perfectly to control the direction of the motors. In this example, we're using the SparkFun Motor Driver which has various pins that need to be connected to C.H.I.P. (Figure C, page 45).

First, connect the motor driver's VM pin to the BAT pin on C.H.I.P., and connect the VCC, PWMA, STBY, and PWM B pins to C.H.I.P.'s VCC-5V line to provide power and enable the motors. Then connect all GND connections to GND on C.H.I.P.

Now connect the I/O signals to tell the motors what direction to move. Sending a logic signal to one pin will drive the motor forward, and sending another will reverse it. This controls the eyes moving up and down and the mouth being opened or closed.

Connect the motor driver's AIN1 pin to C.H.I.P.'s XIO-P0 pin, AIN2 to XIO-P2, BIN1 to XIO-P4, and BIN2 to XIO-P6. Finally, connect the motor driver's A01 and A02 pins

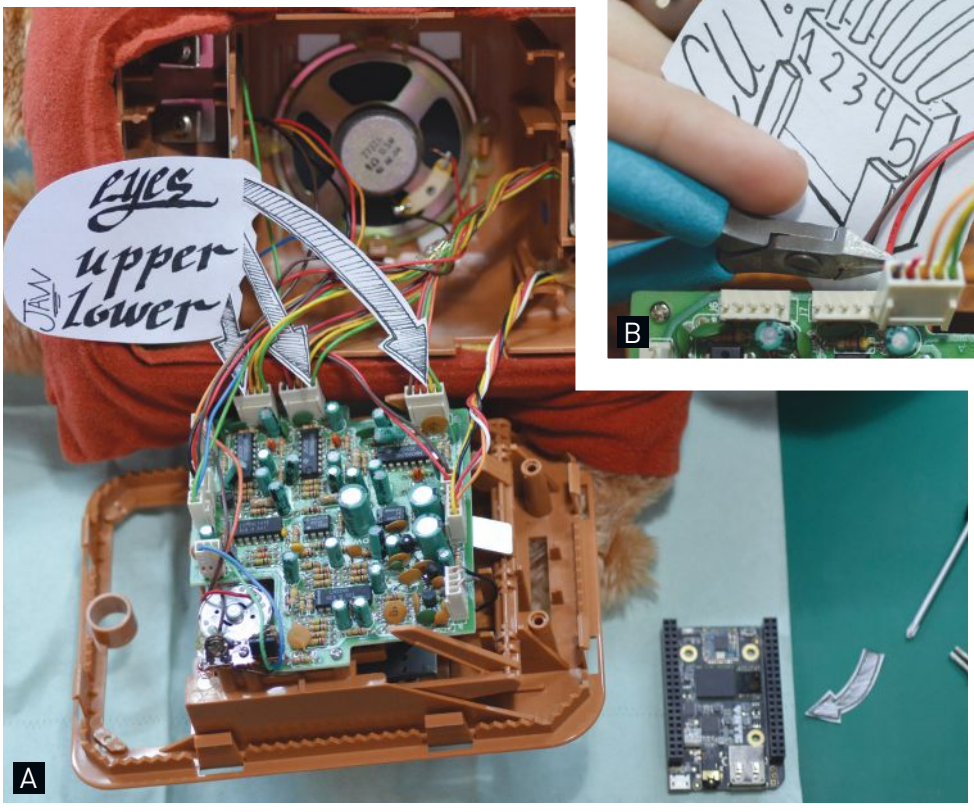
ANDREW LANGLEY is a software and hardware developer at Next Thing Co. who previously worked as a programmer, designer, and writer for Telltale Games on titles such as *The Walking Dead* and *Minecraft: Story Mode*. He also had a brief appearance in the movie *Problem Child*.

Materials

- **C.H.I.P. single-board computer** $9 from Next Thing Co., nextthing.co
- **Teddy Ruxpin toy, functional** We used a 1985 model; your mileage may vary.
- **H-bridge dual motor driver** TB6612FNG breakout board, SparkFun #ROB-09457
- **Battery, LiPo, 3.7V single cell**
- **Audio cable, 3.5mm**
- **Protoboard and male header pins (optional)** or mini breadboard with jumper wires

Tools

- **Soldering iron**
- **Screwdriver, Phillips**
- **Computer with internet connection** or just connect a keyboard and screen to C.H.I.P.



A

B

Richard Reininger

C.H.I.P. Your Pet

Before Furby, AIBO, or Pleo, 1985's **Teddy Ruxpin storytelling plush bear** from Worlds of Wonder was the first animatronic toy that used data on a tape drive to choreograph motor movements, while also using the tape for audio playback.

Here's how we replaced Teddy's antiquated electronics with a $9 computer to create all-new custom speech with synchronized animatronic movements.

1 **Original servomotors** move the toy's eyes and mouth.

2 **Original speaker** plays speech and other audio.

3 **Remainder of Teddy's antique guts** are removed: circuit board, cassette tape drive, audio/data cassette, and 4 hefty D batteries.

4 **C.H.I.P. computer** connects to internet via onboard Wi-Fi, then converts incoming text or tweets to speech and sends it to the speaker, while analyzing audio amplitude to create synchronized motor signals.

5 **H-bridge motor controller board** on a DIY "shield" plugs into C.H.I.P. and drives the original servos.

6 **3.7V LiPo battery** plugs directly into C.H.I.P. to power everything.

Damien Scogin

to Teddy's upper and lower jaw motors, and B01 and B02 to the eye motor.

To organize these connections, we made a DIY "shield" from protoboard to plug into C.H.I.P.'s I/O headers (Figure D). You could use a mini breadboard and jumper wires.

3. LET THE BEAR SPEAK!

Teddy Ruxpin already has an internal speaker, so we just spliced the 2 wires coming from the speaker to our 3.5mm audio cable and connected it directly to the audio/video jack on C.H.I.P.

Plug the 3.7V LiPo battery into C.H.I.P., and your hardware's all connected. Go ahead and stuff it into the bear (Figure E). It's time to move on to the software side of things.

4. THE SOFTWARE SIDE OF THINGS

Part of the magic of Chippy Ruxpin is controlling it via Wi-Fi. So let's get it connected so you can download the software.

You'll want to log into C.H.I.P.'s operating system to type in some commands. You can either hook up a screen and keyboard to C.H.I.P., or access it over a network by following our tutorials at 42.nextthing.co.

Once logged in, you need to get the Wi-Fi working. Type the following, all on one line:

```
sudo nmcli device Wi-Fi connect
<your Wi-Fi network name/SSID>
password <your Wi-Fi password> if-
name wlan0
```

Now it's time to install the software you need, which you can download by typing these commands into the terminal:

```
cd ~/
sudo apt-get install git
git clone https://github.com/
   NextThingCo/ChippyRuxpin.git
```

This pulls the project's Python code, which is split into various components: an audio

player, a Bottle web framework, a Twitter library, and a class to control the GPIO pins on C.H.I.P. to drive the motors.

Part of the code uses eSpeak, a free text-to-speech engine, to generate a WAV audio file from text. The cool part is our audio code: in addition to playback, it also analyzes the WAV file to evaluate its amplitude. If the audio level is loud, the motors in the jaw will activate, opening the bear's mouth. If it's quiet, it will close. Mouth synchronization makes it magical.

You can start the application by typing this:

```
cd chippyRuxpin
sudo python chippyRuxpin.py
```

You should see a message that looks something like this:

```
CHIPPY RUXPIN IS ONLINE!
In your browser, go to
   http://10.1.2.52:8080
```

Now on any computer, tablet, or smartphone, you'll see a web page with a simple text input box. Typing into this box will send the text to C.H.I.P.'s Python script to generate the voice audio and play it over Teddy's internal speaker with a realistic moving mouth.

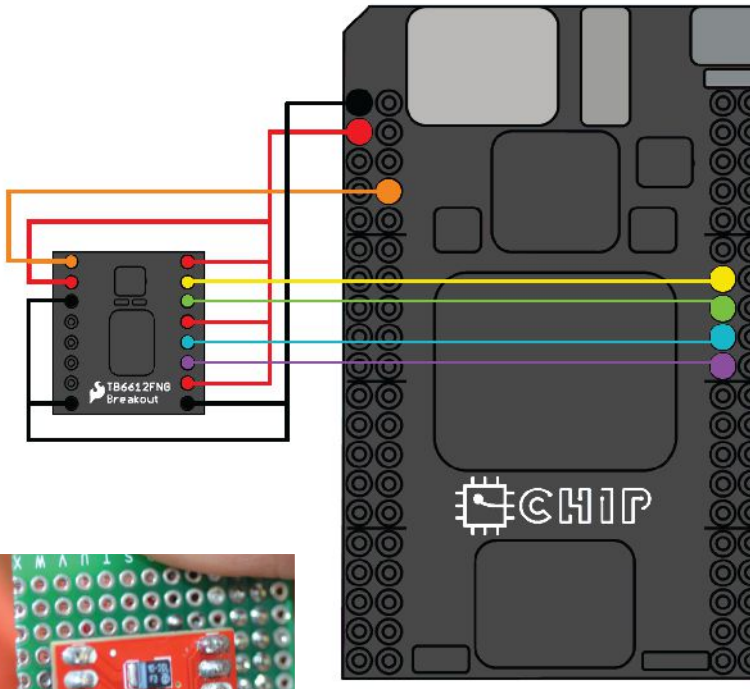
Chippy Ruxpin can also search for tweets and read them out loud. This involves a bit of setup on your part in order to allow C.H.I.P. to access your Twitter account. Instructions can be found in the README file. Imagine the fun of hearing Chippy speak every tweet from @nextthingco, @colbertlateshow, @NASA, or even (caution: definitely NSFW) @WhatTedSaid!

GOING FURTHER

This project only scratches the surface. Perhaps you'd like to take control of Chippy Ruxpin from the other side of the world and have him terrorize your friends. Or have Chippy Ruxpin create his own Wi-Fi hotspot. With C.H.I.P.'s low cost and integrated wireless capabilities, there are endless projects that you can make on your own. ʕ•ᴥ•ʔ

See Chippy Ruxpin in action and share your build on the project page at makezine.com/go/chippy-ruxpin.

C



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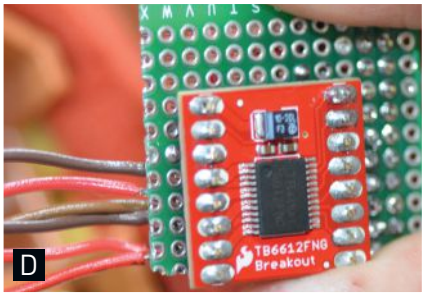

E

Make:
2016 SINGLE-BOARD COMPUTING QUICK REFERENCE GUIDE

Brought to you by

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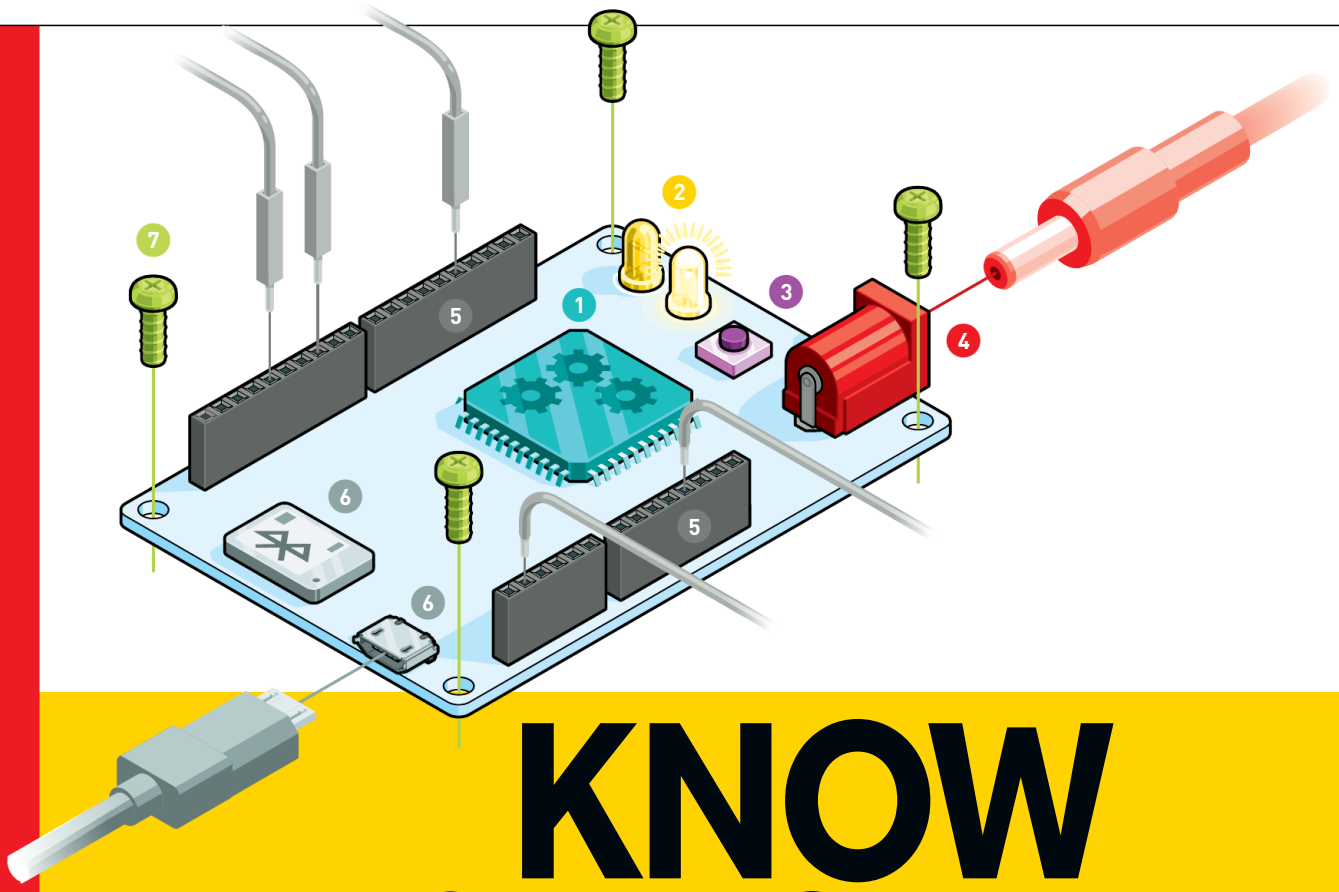


KNOW YOUR BOARD

Written by Kipp Bradford
Illustrated by Rob Nance

FROM ARDUINO TO PI, HERE'S A BREAKDOWN OF WHAT MATTERS

1. Computing
2. Indicating
3. Resetting
4. Powering
5. Interacting
6. Communicating
7. Mounting

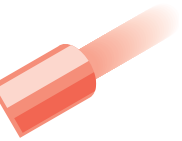
Boards can be divided into two categories: those that can run Linux, like Raspberry Pi, and those that can't, like an Arduino Uno. While this is a completely arbitrary distinction, it is also a useful one because it helps to describe what you should expect in terms of board features, complexity, power consumption, and programmability. For the sake of description, we'll call boards that can run Linux "advanced" and those that can't "basic." Here's a breakdown of what matters about any given board.

COMPUTING

Every board has a main chip where the computation or processing of information takes place. It is mostly the differences between chips that distinguish one board from another. Each chip has different capabilities, strengths, and weaknesses.

Basic boards typically have a single chip that can process data in 8bit or 16bit chunks. These boards run your program at lower processing speeds, in the millions or tens of millions of computations per second. The chip that runs a basic board usually includes all the electronics necessary to easily interface with the real world, like analog inputs, timer inputs and outputs, and more.

Advanced boards generally use a 32bit or 64bit main chip that integrates all of the components that you'd typically find on a computer motherboard into a single device. Sometimes these are called



"system on chip" or SoC. The main chip on an advanced board can run just as fast as a phone or tablet, processing your software in the hundreds of millions or even billions of computations per second. All this, squeezed inside a circuit board that fits in the palm of your hand for less than the cost of a movie ticket. Wow!

INDICATING

Everyone likes blinky LEDs, and every board should have at least a power LED and a software-controlled LED. The power LED is critical for letting us know at a glance when the board is properly plugged in. One or more software-controlled LEDs is a must. Frequently, the first thing people do with a new board is to blink an LED. It lets us know that we've got things working.

OH NO! BUTTON (RESETTING)

Even though we'd like to think that our software is perfect, there are always circumstances that cause software to break. The reset button sends your board back to the beginning of your program so you can watch it crash again — and hopefully figure out what went wrong. Every good board has a reset button.

POWERING

USB, batteries, and wall warts are pretty typical sources of power for boards. Problem is, except for 5V USB, all these sources have a pretty wide range of voltages, while the computer chips on most boards need a fixed voltage. So the power section of a board includes a voltage regulator that takes electricity from the power input jack and converts it to the correct fixed voltage for the chip.

Basic boards typically run at 5V or 3.3V, though some are designed to run off batteries and will accept voltages between 5V and 3.3V and even down to 1.8V. Basic boards might draw anywhere from a few microwatts to maybe a watt or two. The lower the wattage, the longer your device will run from a battery. A well-designed basic board can run for months or years from a couple of AA batteries.

Advanced boards tend to require 3.3V or 1.8V. The processor chips themselves may run at even lower internal voltages of 1.1V or 0.7V. These lower voltages help reduce power consumption at very fast computing speeds. Even at these reduced voltages, expect typical power consumption to be in the hundreds of milliwatts up to tens of watts. That translates to hours or days of runtime from standard AA batteries.

INTERACTING

Computers are much more fun when we can hook them up to things and make those things smart. Most boards have at least simple inputs and outputs (I/O) for interfacing with a wealth of signals in the real world. Almost every board can handle basic digital voltages and signals. Many boards can also handle analog voltages, which can be anything from zero volts up to the chip's power supply voltage.

Basic boards have at least digital I/O, which can be enhanced with many capabilities to expand what the board can do, such as reading or writing data to an SD card, or communicating with other devices using protocols like I2C, SPI, or CAN. Basic digital I/O can be reconfigured to handle different kinds of signals and may also include timer or counter functionality.

Many basic boards have the ability to convert a signal that is between 0V and the supply voltage into a digital representation of that voltage, called "Analog to Digital Conversion." Many sensors and components like potentiometers generate analog voltages that must be converted into useful digital information, which is where an analog to digital converter comes in handy. Occasionally basic boards will also have a "Digital to Analog" converter, which generates an output voltage that can be between 0V and the supply voltage.

Advanced boards usually have everything that basic boards have plus some great extras. Since these boards are basically computers on a chip, they tend to also have a more desktop computer-like, built-in peripheral set that can include HDMI or other video, audio in and out, eSATA for hard drives, external memory, USB host, Ethernet, etc.

COMMUNICATING

Sometimes we want our board to talk to other boards, to a computer, or to the internet. This is done through a communicating interface.

Basic boards can at least send and receive data using one of the oldest and simplest inter-computer communication standards still in common use, RS232. This was the way that everything connected before USB came around. Now many basic boards also have USB or Bluetooth communication interfaces as well.

With advanced boards, connecting things to Wi-Fi or the internet is more sophisticated than simple board-to-board communication. Advanced boards have the extra memory and computing power required to process TCP/IP and other data passed along via Ethernet or Wi-Fi interface electronics.

MOUNTING

Well-designed boards include some way to mount the board to your project. Typically this means the board has several mounting holes designed for screws. They should be spaced far enough away from any components or traces so that the head of the screw doesn't contact anything electrical that could damage the board.

Advanced boards may also have grounding screws that connect the ground plane on a board to its metal case to reduce electrical noise and interference.

KIPP BRADFORD is a biomedical engineer and Research Scientist at the MIT Media Lab. He has founded startups in the fields of transportation, consumer products, HVAC, and medical devices, and holds numerous patents.

TABLE OF BOARDS

Written by David Scheltema

The art of choosing a board is knowing when to go to the specs. Start with the general project idea. Make a list of the features the project requires. Then, and only then, jump into the specs to determine which board is right for your next project.

Depending on the application, certain specs will be more important than others. In a purely software project, board features such as the developer tools, memory, and clock speed will matter much more than the video output or board dimensions. For projects that measure environmental data specs such as radio connectivity, digital and analog I/O are far more important than clock speed.

As it turns out, specs lists and data-sheets distributed by manufacturers are not always intended to be technical references, so much as they are designed as marketing copy. In fact, compiling a list of boards that compares similar features is not easy. With considerable research, we've put together the following spec sheet, but it's far from a complete technical reference.

The boards listed here are just a sample of what is available on the market now. We've made sure to include the most popular and interesting options; for even more, visit makezine.com/comparison/boards.

Finally, a request: Board manufacturers and vendors alike should aim to provide clear, standardized specs for the good of the community. Just as open source hardware and software inform and enable a stronger community, a concise list of easily accessible data points about a boards — and products in general — makes everyone better off.

Board Name	Price	Size	Type (microcontroller, single board computer, FPGA)	Software
Arduino Mega	$46	4in×2.1in	MCU	Arduino
Arduino Uno	$25	2.7in× 2.1in	MCU	Arduino
Arduino Yún	$69	2.7in×2.1in	MCU	Arduino
Arduino Zero	$50	2.7in×2.1in	MCU	Arduino
Arrow SmartEverything	$118	2.1in×2.7in	MCU	Arduino
Banana Pi	$65	3.6in×2.4in	SBC	Linux
Bare Conductive Touch Board	$80	3.3in×2.4in	MCU	Arduino
BeagleBone Black	$55	3.4in×2.1in	SBC	Debian Linux
BeagleBone-X15	$239	4in×4.2in	SBC	Debian Linux
RedBear Blend	$33	2.9in×2.1in	MCU	Arduino
C.H.I.P.	$9	1.5in×2.3in	SBC	Linux
DFRobot Leonardo with Xbee socket	$20	2.8in×2.2in	MCU	Arduino
ESP8266	$3-7	1.4in×1in	MCU	Arduino, Lua, AT-commands
Espruino	$40	2.1in×1.6in	MCU	Espruino JavaScript Interpreter
Flora	$20	1.8in dia.	MCU	Arduino
Gemma	$10	1.1in dia.	MCU	Arduino
Intel Edison with Arduino Breakout	$70	1.4in×1in	SBC	Poky Linux, Arduino
Jetson TK1	$192	5in×5in	SBC	Linux
Kinoma Create	$150	5.13in×5.2in	SBC	Custom Linux, Kinoma Studio IDE
LightBlue Bean	$30	1.8in×0.8in	MCU	Arduino

	Operating Voltage (tolerance range)	Clock Speed	Radio	Video	Ethernet Ports	I/O Digital	I/O Analog	Memory	Website
	6V–20V	16MHz	–	–	–	54 (15 PWM)	16	256KB flash	arduino.cc
	6V–20V	16MHz	–	–	–	14 (6 PWM)	6	32KB flash	arduino.cc
	5V	16MHz & 400MHz	Wi-Fi	–	–	20 (7 PWM)	12	32KB flash	arduino.cc
	7V–12V	48MHz	–	–	–	20 (18 PWM)	6 in, 1 out	256KB flash	arduino.cc
	5V–45V	48MHz	SigFox, Bluetooth	–	–	14	6	256KB	smarteverything.it
	5V	1GHz	–	HDMI	Yes	26	–	SD	bananapi.org
	5V	16MHz	–	–	–	20 (7 PWM)	12	32KB flash, microSD	bareconductive.com
	5V	1GHz	–	Micro-HDMI	Yes	65 (8 PWM)	7	4GB eMMC	beagleboard.org
	12V	Dual-core 1.5GHz	–	HDMI	Yes, GB	157	–	4GB-8bit eMMC	beagleboard.org
	6.5V–12V	16MHz	Bluetooth	–	–	14 (PWM 5)	6	32K flash	redbearlab.com
	3.7V–5V	1GHz	Wi-Fi, Bluetooth	Composite via TRRS jack	–	8 GPIO, SPI, I2C, UART, CSI, Parallel LCD	1	4GB eMMC	getchip.com
	7V–12V	16MHz	Wi-Fi, Bluetooth	–	–	20 (7 PWM)	12	32KB flash	dfrobot.com
	3V–3.6V	80MHz	Wi-Fi	–	–	2	1	1MB	espressif.com
	1.6V–15V	72MHz	–	–	–	44 (26 PWM)	16 ADC, 2 DAC	256KB flash	espruino.com
	3.5V–16V	8MHz	–	–	–	8 (3 PWM)	4	32KB flash	adafruit.com
	4V–16V	8MHz	–	–	–	3 (2 PWM)	1	8KB flash	adafruit.com
	7V–15V	Dual-core 500MHz	Wi-Fi, Bluetooth	–	–	20 (4 PWM)	6	4GB eMMC flash	intel.com
	12V	Quad-core 2.32GHz	-	HDMI	Gigabit	125 pins (7GPIO)	-	16GB eMMC, SD	nvidia.com
	3.7V	800MHz	Wi-Fi, Bluetooth	Built-in touchscreen	–	66 (3 PWM)	17	microSD	kinoma.com
	3V	8MHz	Bluetooth	–	–	6 (PWM 4)	2	32KB flash	punchthrough.com

Board Name	Price	Size	Type (microcontroller, single board computer, FPGA)	Software	Operating Voltage (tolerance range)	Clock Speed	Radio	Video
LinkIt One	$59	3.3in×2.1in	MCU	Arduino	3.7V–4.2V	260MHz	Wi-Fi, Bluetooth	–
MicroPython pyboard	$42	1.7in×1.66in	MCU	MicroPython	3.6V–16V	168MHz	Wi-Fi	–
MinnowBoard Max	$145	2.9in×3.9in	SBC	Linux	5V	Dual-core 1.33GHz	–	Micro-HDMI
Netduino 3	$70	3.3in×2.1in	MCU	.NET Micro Framework 4.3	7.5V–12V	168MHz	–	–
Particle Electron	$39 (2G) / $59 (3G)	2.0in×0.8in	MCU	Arduino	3.3V	120MHz	Cellular	–
Particle Photon	$19	1.44in×0.8in	MCU	Arduino	3.3V	120MHz	Wi-Fi	–
pcDuino Acadia	$120	4.7in×2.6in	SBC	Linux	5V	Quad-core 1.2GHz	–	HDMI
Propeller Activity Board	$50	4.0in×3.05in	MCU	SimpleIDE, Propeller Tool	6V–9V	Octo-core 80MHz	XBee Ready	Composite
Raspberry Pi 2	$40	3.4in×2.2in	SBC	Linux	5V	Quad-core 900MHz	–	HDMI
Raspberry Pi Zero	$5	1.18in×2.56in	SBC	Linux	5V	1GHz	–	HDMI Mini
RePhone	$59	1in×0.8in	MCU	Arduino	3.3V–4.2V	260MHz	–	TFT display
RFduino	$29	0.9in×1.514in	MCU	Arduino	2.1V–3.6V	16MHz	Wi-Fi, Bluetooth	–
RIoTboard	$79	3in×4.7in	SBC	Linux, Android	5V	1GHz	–	HDMI, LVDS, LCD
Snickerdoodle	$55	2in×3.5in	FPGA	Linux	3.7V–17V	Dual-core 667MHz	Bluetooth	–
Teensy 3.2	$20	1.4in×0.7in	MCU	Teensyduino	3.3V	72MHz	–	–
TinyLily Mini	$10	0.55in dia.	MCU	Arduino	2.7V–5.5V	8MHz	–	–
Trinket 3.3V & 5V	$7	1.1in×0.6in	MCU	Arduino	3.3V–16V	3.3V @ 8MHz, 5V @ 8MHz or 16MHz	–	–
UDOO Neo Full	$65	3.5in×2.3in	SBC	Linux	6V–15V	1GHz	Wi-Fi, Bluetooth	Micro-HDMI
WiPy	$32	1.7in×1in	MCU	MicroPython (Python 3.4 Syntax)	3.6V–5.5V	80MHz	Wi-Fi	–
Xadow	$130 (kit)	1in×.081in	MCU	Arduino	3.3V	16MHz	–	–

	Ethernet Ports	I/O Digital	I/O Analog	Memory	Website
	–	16 (2 PWM)	3	16MB flash, microSD	seeedstudio.com
	–	30 (20 PWM)	16	1024KB flash, microSD	micropython.org
	Yes, GB	8 GPIO, I2C, I2S Audio, 2 UART, SPI (2 PWM)	–	8MB SPI Flash, microSD	minnowboard.org
	–	22 (6 PWM)	6	384KB flash	netduino.com
	–	30 (15 PWM)	12 ADC, 2 DAC	1MB flash	particle.io
	–	18 (PWM 9)	8 ADC, 2 DAC	1MB flash	particle.io
	Yes	14 GPIO	6	microSD	linksprite.com
	–	18	4 ADC, 2 DAC	microSD	parallax.com
	Yes	26 GPIO	–	microSD	raspberrypi.org
	–	26 GPIO	–	microSD	raspberrypi.org
	–	16 (1 PWM)	2	5MB flash	seeedstudio.com
	–	7 (Software PWM)	–	128KB Flash	rfduino.com
	Yes	40 (3 PWM)	–	4GB eMMC, SD, & microSD	riotboard.org
	–	33x GPIO, 4x I2S audio, 14x I2C, 1x ADC, 2x DAC	16	microSD	krtkl.com
	–	34 (12 PWM)	21	256KB	pjrc.com
	–	8 (2 PWM)	4	32KB flash	tiny-circuits.com
	–	5 GPIO (2 shared w/USB 3 PWM)	3	8K flash	adafruit.com
	yes	32 (8 PWM)	6	microSD	udoo.org
	–	25 (4 PWM)	3	2MB flash	wipy.io
	–	20 (7 PWM)	12	32KB flash	seeedstudio.com

EXPANSION BOARDS!

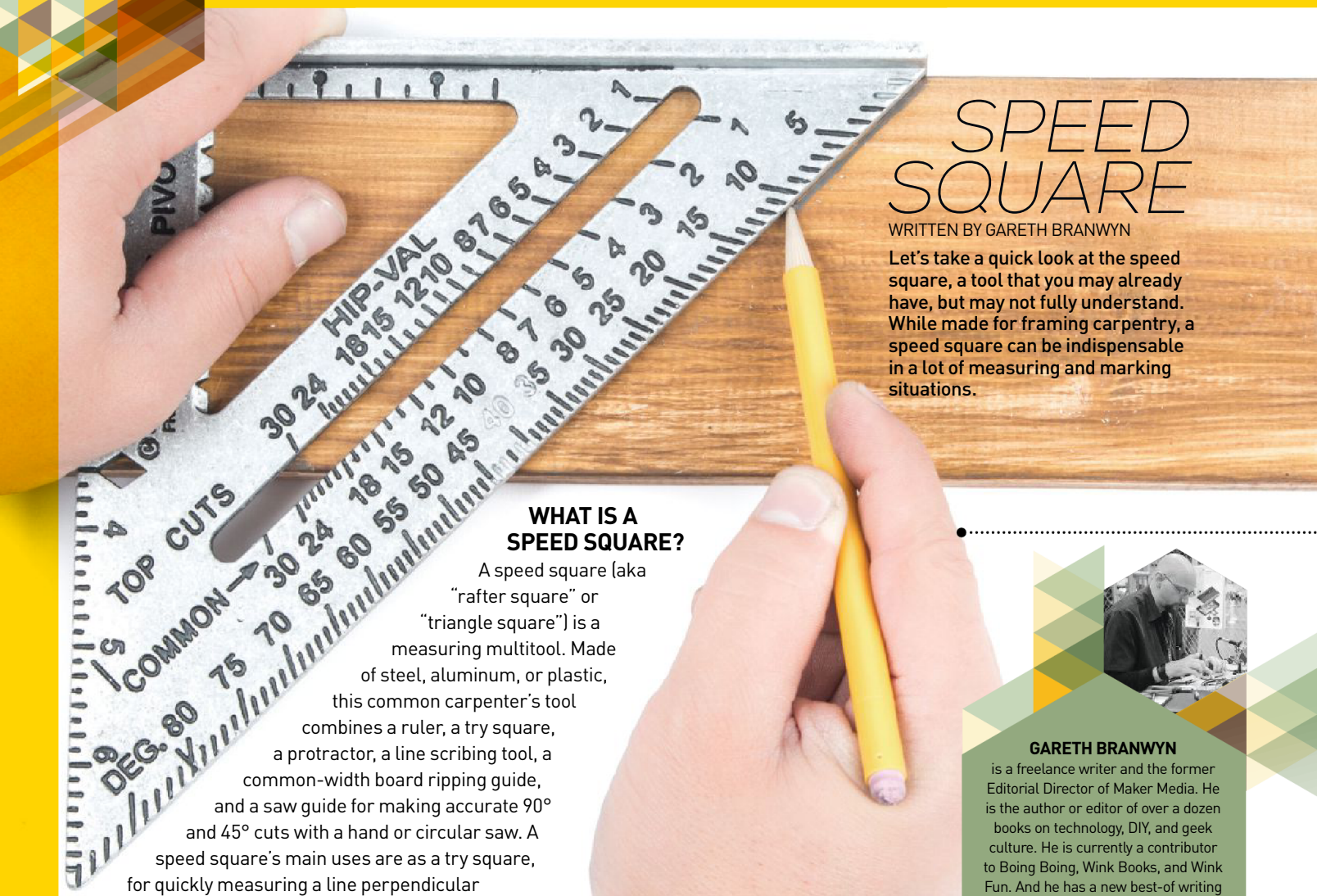
Written by Kipp Bradford

CALLED HATS, CAPES, AND SHIELDS, THESE ADD-ON UNITS CAN TAKE YOUR BOARD PROJECT TO THE NEXT LEVEL

- **MOTOR** boards control hobby servos as well as stepper, brushed, and brushless DC motors. Available for everything from small pager motors to units rated one horsepower or more.
- **DISPLAY** boards may control a small text or graphic LCD display directly, or they can generate video signals for HDMI, VGA, and old-school composite monitors.
- **AUDIO** boards convert signals from a microphone or audio input into digital data, as well as change digital data into audio waveforms for output.
- **PROTOTYPING** boards let you permanently connect wires and components to a project.
- **PHYSICAL INTERFACE** boards offer general combinations of inputs like joysticks, pushbuttons, or knobs. On the output side, mechanical or electrical relays are pretty typical.
- **STORAGE** boards typically have flash memory, often in the form of card slots for SD or microSD cards. Useful for logging data or playing back audio and video to a display.
- **SENSING AND MEASURING** boards can measure light, sound, temperature, air pressure, acceleration, rotation, position (GPS), and more.
- **COMMUNICATION** boards offer Wi-Fi, Ethernet, Bluetooth, cellular, CAN, USB, XBee, RFID, 1-Wire, etc.

Skill Builder

Ready for information overload? In this section we'll cover a broad range of little known tips and tricks to help experts and amateurs alike.



SPEED SQUARE

WRITTEN BY GARETH BRANWYN

Let's take a quick look at the speed square, a tool that you may already have, but may not fully understand. While made for framing carpentry, a speed square can be indispensable in a lot of measuring and marking situations.

WHAT IS A SPEED SQUARE?

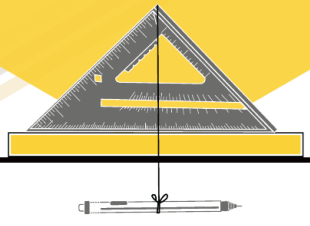
A speed square (aka "rafter square" or "triangle square") is a measuring multitool. Made of steel, aluminum, or plastic, this common carpenter's tool combines a ruler, a try square, a protractor, a line scribing tool, a common-width board ripping guide, and a saw guide for making accurate 90° and 45° cuts with a hand or circular saw. A speed square's main uses are as a try square, for quickly measuring a line perpendicular to the edge of a board (hence the "square" in the name), as a miter square, for accurately marking 45° angles, and as a protractor, for easily finding and marking various common angles, especially roof rafter pitches and angles for stair stringers (the vertical supports on a stairway).

The speed square was invented in 1925 by Albert Swanson. Swanson was a carpenter in a small town outside of Chicago. He wanted to create a device to make it easier to quickly determine roof pitches. After he created the speed square, other carpenters began asking him for one, and the Swanson Tool Company was born. Speed Square is actually a trademarked name, but like Kleenex, it is often used as the generic name for this class of tool. Stanley's similar tool is called a Quick Square and Irwin's is simply called the Rafter Square.

GARETH BRANWYN
is a freelance writer and the former Editorial Director of Maker Media. He is the author or editor of over a dozen books on technology, DIY, and geek culture. He is currently a contributor to Boing Boing, Wink Books, and Wink Fun. And he has a new best-of writing collection and "lazy person's memoir," called *Borg Like Me*.

QUICK TIP

You can also use a speed square as a make-do level when you find yourself without a proper bubble level. You do need a plumb bob, but you can improvise one with a string and a nut (or some other suitable weight).



Hep Svadja

WHAT CAN IT DO?

MARKING

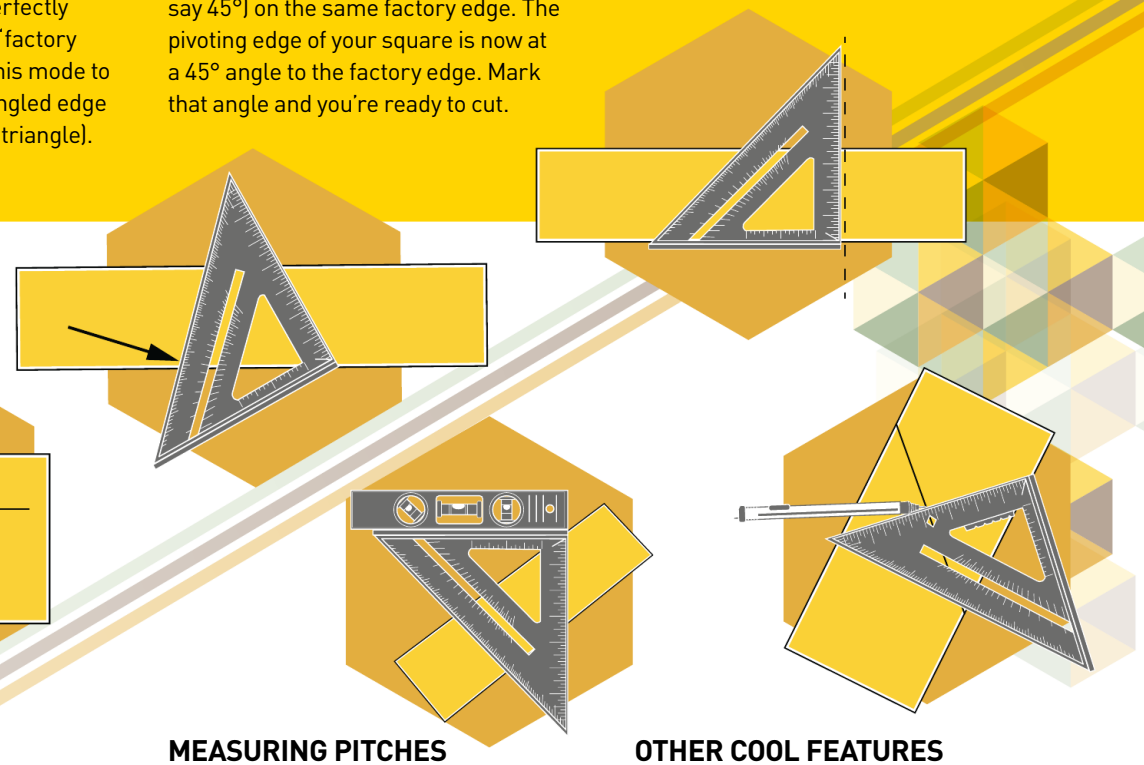
The most commonly used application of the speed square is as a try square. The tool has a lipped fence along one right-angled edge that allows you to hold the square firmly against a board. From there, you can easily and accurately scribe along the other right-angled edge to create a line that is perfectly perpendicular to the board's "factory edge." You can also use it in this mode to scribe 45° angles along the angled edge of the tool (i.e. the base of the triangle).

PROTRACTING

To use the protractor feature, you first find the pivot point marked in the 90° corner of the square. With the pivot mark on the factory edge of your board, you pivot the bottom of the tool (where the protractor degrees are marked) and move it to the desired degree (let's say 45°) on the same factory edge. The pivoting edge of your square is now at a 45° angle to the factory edge. Mark that angle and you're ready to cut.

SAW GUIDE

One of the other common functions of the speed square is as a guide for crosscutting lumber at an accurate 90° or 45° angle. By firmly holding the fence against the edge of a board, you can use the other right-angle or 45°-angle edge as a fence for your hand or circular saw.



MEASURING

Along one of the right-angled edges of the square is a conventional English ruler, which is either 7" or 12" (depending on the model of speed square). Below this ruler, in the triangular cutout, is something called the "scribe bar," which features a series of notches at ¼" intervals. To easily scribe a rip or trim line along a board, simply place the fence against the edge of the board, hold your pencil in the desired notch, and slide the square along the board to make an accurate mark down its length. You can also use the right angle to check internal angles for accuracy on a square.

MEASURING PITCHES

Part of the speed square's role as a protractor, and its original mission as a tool, is in quickly finding common (and uncommon) rafter angles for the pitches on roofs. This is accomplished by use of the main protractor and two specialty protractor angle guides on the inside of the tool. The guide directly above the protractor is marked "Common." On it, common roof pitches are indicated as the rise (in inches, over a 12" run), for common rafters from 1" to 30". Above this guide is another, marked "HIP-VAL." This stands for "Hip-Valley" and refers to the rise over a 12" run for Hip- or Valley-type rafters.

OTHER COOL FEATURES

The Swanson Speed Square has a patented feature — the diamond cut, a diamond-shaped cutout on the ruler edge of the tool. This is used for squaring on a line scribed across the board so that you can then make a perfect 90° line from your scribed angle to the edge of the board — very helpful for making rafter seat cuts.

Jim Burke

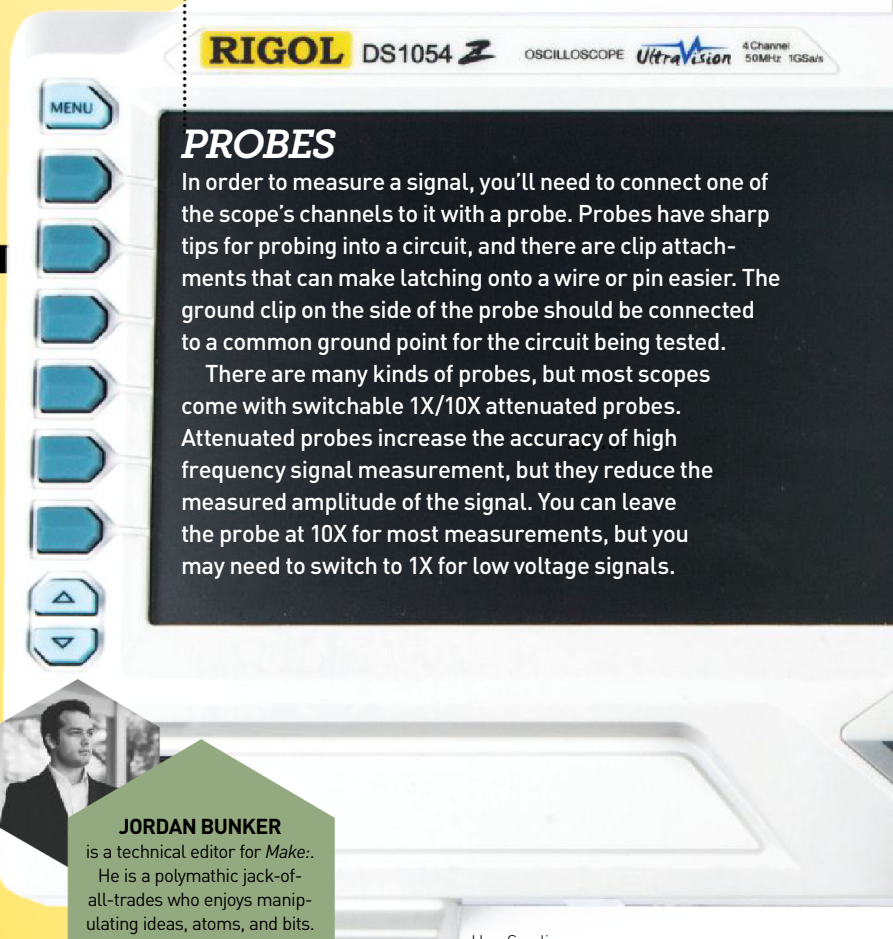
DIGITAL STORAGE OSCILLOSCOPES

WRITTEN BY JORDAN BUNKER

If you're doing any advanced electronics repair, troubleshooting, or reverse engineering, you'll definitely need an oscilloscope. For many years, oscilloscopes were purely analog, using vacuum tubes and electron beams to "paint" the signals onto a phosphor screen, but modern oscilloscopes are now digital and can store signals for later viewing. Since a full how-to on oscilloscopes could fill a small book, we'll cover just the basics of using one to get you started working with these seemingly complex tools.

In the simplest terms, an oscilloscope is a device for showing a graph of how an electrical signal changes over time. The vertical axis of the graph represents voltage, and the horizontal axis represents time. Because digital storage oscilloscopes use an analog-to-digital converter to change measured voltages into digital information, the scope is able to store a series of samples in order to create an approximate waveform and display it on its LCD screen. The waveform can then be analyzed or saved for later review.

Most of the controls on an oscilloscope deal with adjusting the vertical, horizontal, or trigger settings, and they are grouped accordingly into separate sections on the control panel.



PROBES

In order to measure a signal, you'll need to connect one of the scope's channels to it with a probe. Probes have sharp tips for probing into a circuit, and there are clip attachments that can make latching onto a wire or pin easier. The ground clip on the side of the probe should be connected to a common ground point for the circuit being tested.

There are many kinds of probes, but most scopes come with switchable 1X/10X attenuated probes. Attenuated probes increase the accuracy of high frequency signal measurement, but they reduce the measured amplitude of the signal. You can leave the probe at 10X for most measurements, but you may need to switch to 1X for low voltage signals.

GENERAL OSCILLOSCOPE SPECS

BANDWIDTH describes the range of frequencies the oscilloscope can reliably measure.

SAMPLING RATE governs how many times per second a signal is read. Since digital scopes take samples of a signal in order to reconstruct a waveform, the higher the sample rate, the more accurate the displayed waveform.

RESOLUTION describes how precise the voltage measurement of a signal is.

TIME BASE allows you to control how frequently a digital scope digitizes samples from an input signal. When you adjust the horizontal scale on the scope, you are adjusting the time base.

CHANNELS are the number of signals a scope can read, with each signal being input in a separate channel. Most mid-level oscilloscopes can display two or more signals on a screen at a time.

JORDAN BUNKER is a technical editor for *Make:*. He is a polymathic jack-of-all-trades who enjoys manipulating ideas, atoms, and bits. Find him in his basement workshop in Oakland.

Hep Svadja

HORIZONTAL (TIME)

The horizontal axis of the oscilloscope screen shows the duration of time for a waveform.

POSITION This knob allows you to control the viewed portion of the waveform in its duration. You can think of this as moving the wave left or right.

SCALE This knob changes the time base, allowing you to display a smaller or larger chunk of time of the waveform, changing the seconds per division shown.

TRIGGER

The trigger settings tell the scope what parts of a signal to "trigger" on and start sampling. This helps stabilize the wave displayed on the screen and makes it appear to be static.

LEVEL This knob sets the voltage level that will trigger the scope.

TYPE The various trigger types set the kind of wave shape or pattern that the oscilloscope triggers on. Common types include edge, pulse, and delay. For more in-depth descriptions of the trigger types available on your oscilloscope, it's a good idea to consult the manual.

MODE Most oscilloscopes have multiple trigger modes, but the most common are normal, single, and automatic. Normal mode triggers the collection of a waveform only when the signal reaches the set trigger conditions. Single mode waits until the trigger condition is detected, then acquires a single waveform and stops. Automatic mode starts the collection of a waveform even when the trigger conditions have not been reached, forcing it to trigger after a specific period of time.

VERTICAL (VOLTAGE)

The vertical axis on the oscilloscope screen shows the amplitude of a waveform.

POSITION This knob adjusts the voltage offset of the displayed signal, moving it up or down on the display.

SCALE This knob adjusts the scale of displayed voltage on the screen, changing the volts per division displayed.

INPUT COUPLING This may be a button, or it may be in a menu setting, but it controls whether a channel is AC, DC, or ground coupled. DC coupling shows all of the input signal, while AC coupling blocks any DC component of the signal so that you see the AC portion centered on zero volts. Ground coupling shows you ground, and is useful as a reference when comparing signals from multiple channels.

MATH Many oscilloscopes have a "MATH" button, which can perform operations on the displayed waveform and overlay the result on-screen. This is useful for performing advanced analysis of waveforms on the fly.

ELECTRONICS ENCLOSURES

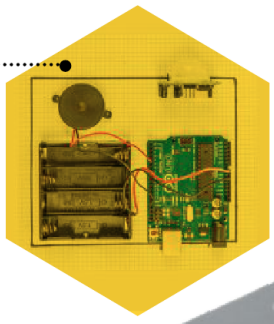
WRITTEN BY MATTHEW BORGATTI

Virtually every electronics project will end up in an enclosure. The project box is an essential, unsung hero of the electronics world, and how you design yours can be the difference between your installation coming off without a hitch or disappearing in a cloud of blue smoke.

LAYOUT & PREP

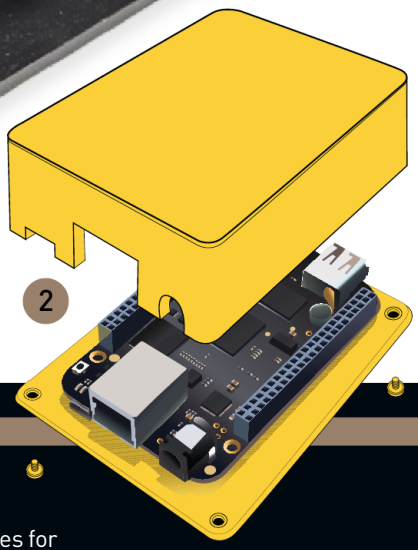
To get a sense of how big your enclosure needs to be, where your components will fit best, and what's going to work for your external connectors, start by laying out all of your parts in real space. If you don't have all of your components on hand, draw or print out their footprints from datasheets scaled to the appropriate size.

Printouts can also be helpful in laying out holes — you can mark the centers of the component holes in your printout and tape them to your enclosure temporarily. Mark the centers with a punch and a light tap with a hammer to create a divot in the enclosure's surface to help when drilling.



Hep Svadja

1



2

Jim Burke

MATTHEW BORGATTI is a Maker, designer, and engineer. He's the lead scientist at Super-Releaser, a soft robotics laboratory that takes experimental robotics technologies and applies them to practical problems.

ENCLOSURE TYPES

Enclosures can take a lot of forms, from off-the-shelf boxes for quick, simple projects, to custom 3D printed cases with clever snap fasteners built in. What format you choose should be guided by what kind of environment the enclosure will experience.

A **sandwich enclosure** 1 is a good compromise between speed and security. A sandwich enclosure is simply two boards separated by standoffs with your components between them.

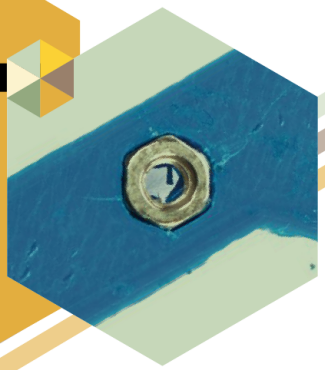
One popular method is to **laser cut the base** 2 on which the components will be laid out, and 3D print a lid to secure to the base using snaps or screws.

Creating your own custom enclosure from scratch offers opportunities for clever design elements, convenient fasteners, and secure connections, but it can require substantial investment of time and effort.

Experiment with different arrangements for your components and different configurations for your enclosure. It's easy to create a puzzle box that's irritating to put together, take apart, and service.

FABRICATION & ASSEMBLY

There are many fasteners and connectors that make it easier to put your custom case together.



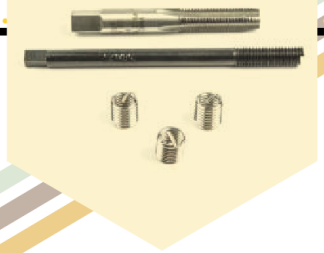
Hep Svadja

CAPTIVE NUT

You can quickly get a fastener inserted into your print by creating a cavity the same profile as a hex nut, just a quarter of a millimeter wider. A screw coming in from a through hole opposite the cavity will get caught by the hex nut.

HEAT-SET THREADED INSERTS

Useful for attaching strong threaded holes to FDM printed enclosures. These can be melted into a hole in your print using a soldering iron.



HELICOILS

A method for adding metal threads to any hole. Run the proper size tap into your hole and then follow it up with the helicoil insert. These are a convenient feature for plastic parts that will see a lot of service and their screws installed and uninstalled dozens of times. You can replace helicoils if they ever wear out without having to re-drill the hole.

DRILLING HOLES IN PLASTIC

Jim Burke

Chances are your next project box is going to be made of plastic. Plastic is easy to find, light, strong, and cheap. However, it can be a little frustrating to drill.

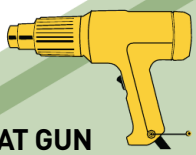
You can find specialty drills made just for plastic. They're pretty cheap and their biggest appeal is that they keep the plastic from climbing the drill flutes as it approaches the end of the hole.

You can get a high-quality hole using just about any drill bit as long as you use a drill press and clamp your piece down before drilling.

To get accurate holes, make sure to scribe the hole's location beforehand and mark it with a center punch. The divot a center punch leaves in durable plastics like nylon and Delrin is an ideal starting point for small drills.

TOOLS

Here are some helpful tools to make your next project box the best you've ever built.

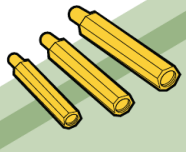


HEAT GUN

It's simple enough to shrink heat tubing with a lighter, but when you can get a heat gun for less than ten bucks and find yourself making strain relief wraps for a hundred bundles of wires, you'll be glad you've got one on hand.

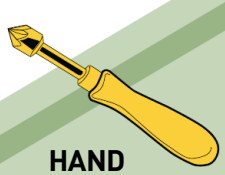
WASHERS

Washers are one of the dirty little secrets of fabrication. Did you accidentally buy screws that are a few mm too long? Did you accidentally drill a hole that's a touch too large for your fastener's head? Washers to the rescue.



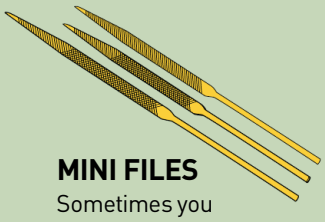
STANDOFFS

Having standoffs on hand saves a lot of headaches when it comes to connecting circuit boards to just about everything. Buy a cheap set that includes a few different lengths of male/male, male/female, and female/female standoffs.



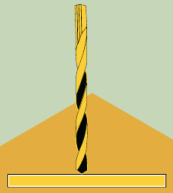
HAND COUNTERSINK

For cleaning up small holes, nothing beats a hand countersink. You can even find ones with deburring tools built in for cleaning up the edges of freshly cut pieces of metal or plastic.



MINI FILES

Sometimes you have to take a nibble out of a case to get a wire fitting through correctly. You can get sets of small files with different profiles that are great for this kind of mod. They usually come in cheap plastic bags, but they store really well in a pencil case.



QUICK TIP

For hard plastics that might shatter from the force of a center punch, you can twist a starting divot into its surface with a ⅛" twist drill. Just give the drill a few turns until some chips form.

HOT GLUE

WRITTEN BY JORDAN BUNKER

Hot melt adhesive, more commonly known as hot glue, is the go-to glue for most crafters, but it's very useful in a huge number of different hobbies. Here are some ideas and advice that just might make hot glue your new favorite adhesive.

GLUE STICKS

Glue sticks are available in a variety of colors, even glitter-filled and glow-in-the-dark. There are also low- and high-temperature glues, with the high-temperature version producing a stronger bond. Dual-temperature hot glue guns are available, which allow you to switch temperatures for either glue stick type.

CANNED AIR

When you're in a hurry, it can be incredibly frustrating to wait for hot glue to dry. To cool it instantly, take a can of compressed air, turn it upside-down, and spray the freshly glued area. The spray that comes out of the can chills the glue, solidifying it in seconds. Be careful not to spray your hands or anything that shouldn't get cold, as it can burn your skin.

HEAT GUN

If you need to re-adjust a hot-glued area, you can use a heat gun to heat the glue back up and reposition it.

Hep Svadja

QUICK TIP

Hot glue can stick to your skin and cause painful burns, and it's nearly impossible to remove until after it solidifies. It's a good idea to keep a bowl of cold water nearby so you can dip your hand in it and cool the glue faster to minimize the burn.

CASTING

Hot glue isn't just an adhesive, it can be used for casting small objects. Just make a quick plaster (or 3D printed) mold of the object you want to duplicate, then squirt hot glue into the negative space after the mold has hardened.

MAT

Before you plug in that hot glue gun, put a silicone mat or some parchment paper (not wax paper!) down on your workspace. Any spilled hot glue can be peeled off after it cools.

DENATURED ALCOHOL

If you ever need to remove hot glue from something, you can use a small amount of denatured alcohol along the edges of the glue to break the bond.

Make:

GETTING STARTED KIT

Arduino, Special Edition

THIS KIT MAKES IT EASY TO GET STARTED WITH ARDUINO

Let Arduino Co-Founder Massimo Banzi walk you through the basics with the *Make: Getting Started with Arduino* book, then put your new-found skills into practice with the included Arduino Uno R3.

Whether you have a specific project in mind or just want to experiment, the solderless breadboard and assortment of LEDs, resistors, buttons, and jumper cables in the box will have you up and running in no time.

Maker Shed

MAKERSHED.COM/PAGES/KITS

Written by Jim Becker

DIY Concrete Lantern

Inspired by Japanese gardens, it's easy to cast and looks good for decades!

Time Required: 4-6 Days
Cost: $100-$200

JIM BECKER has been building things since he was 8. After getting a degree in biomedical engineering at Brown University in 1977, he started becker&mayer! with his high school buddy Andy Mayer. The company grew to become the largest book producer in the United States, creating among other things science kits for Scholastic and novelty book formats for Lucasfilm. Currently Jim is creative director for SmartLab, an award-winning science toy company that's a division of becker&mayer.

Materials

- **Quick-set concrete, 60lb bags (6)** such as Quikrete
- **Construction grout, 50lb bag** aka structural grout
- **Plywood, 5/8", 4'×8' sheets (2)** CDX or other non-appearance grade
- **Sheet metal screws, 5/16" hex head, 1/2" long (50)**
- **Wood screws or drywall screws, 1" (50)**
- **Angle brackets, 90°, 1" (20)**
- **Duct tape, 2" wide, high quality**
- **Scrap lumber, 2×2, 12"–18" length**
- **Concrete adhesive, 10 oz tubes (2)** such as Quikrete Polyurethane Construction Adhesive
- **Rigid foam insulation, 1" thick, approx. 12"×30"**

Tools

- **Circular saw (preferred) or table saw** with general purpose blade
- **Power screwdriver**
- **Socket set, 1/4" drive**
- **Sandpaper**
- **Level**
- **Measuring cup, 1qt**
- **Tub, approx. 12"×16"×6"** for mixing concrete
- **Dust mask or respirator** for mixing concrete
- **Tarp, 8'×8' minimum** for the mess
- **Trash bags, heavy-duty**
- **Drill with 1/2" bit**
- **Keyhole saw**
- **Handsaw**
- **Caulking gun**

Osmosis Spa (osmosis.com)

I WAS IN JAPAN EIGHT YEARS AGO AND LIKE A GOOD TOURIST, I WENT TO MANY JAPANESE GARDENS, WHICH WERE AMAZING. A ubiquitous feature of Japanese gardens is concrete and stone lanterns in endless shapes and sizes. When I came back home, I decided to build one myself.

This lantern is my design; it's not based on any particular build, but it's representative of many traditional garden lanterns.

While making this lantern is not difficult, there are lots of steps, so for the sake of brevity I drew some diagrams that Makers can follow.

All the forms for casting the pieces of the lantern are made from ⅝" plywood. I used inexpensive CDX grade, which leaves a subtle wood grain texture on the concrete. You can use a smoother grade of plywood if you want a smoother finish.

CAST YOUR CONCRETE LANTERN

The lantern has 6 pieces: a base, column, pedestal top, window box, canopy, and cap. You can download all the full-size diagrams on the project page at makezine.com/go/concrete-lantern.

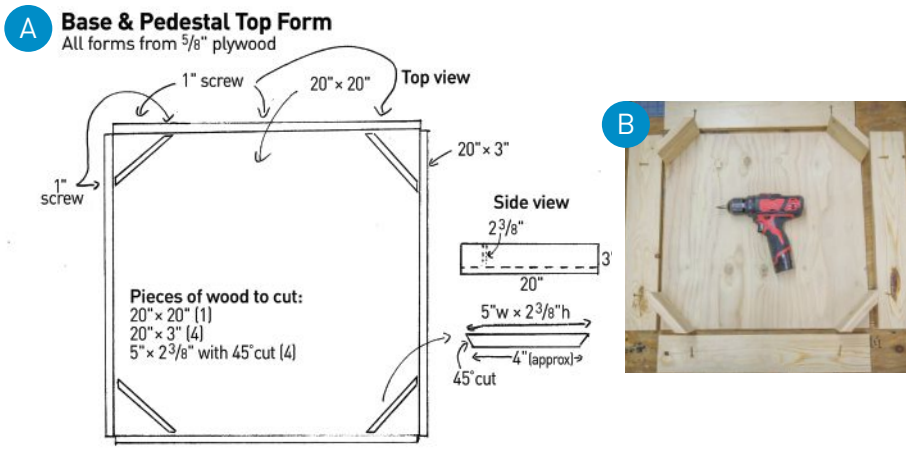
1. BUILD THE BASIC FORMS

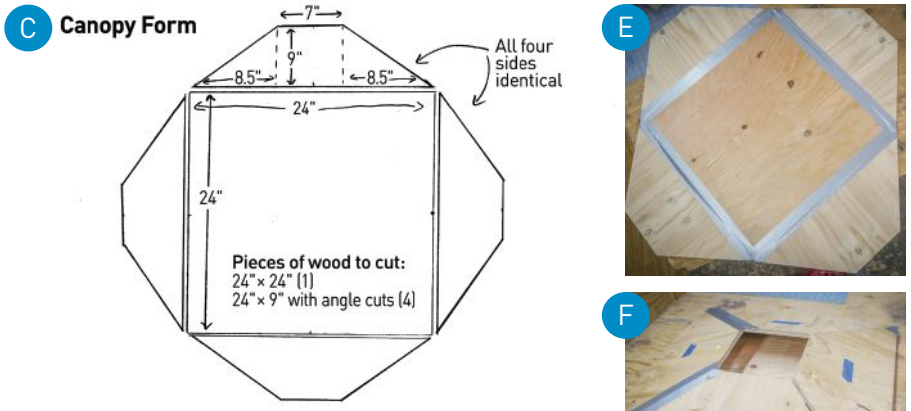
You'll use mainly 1" screws, or simple 1" angle brackets with ½" screws, to connect the plywood pieces together. If desired, you can sand down rough spots or smooth them with wood filler.

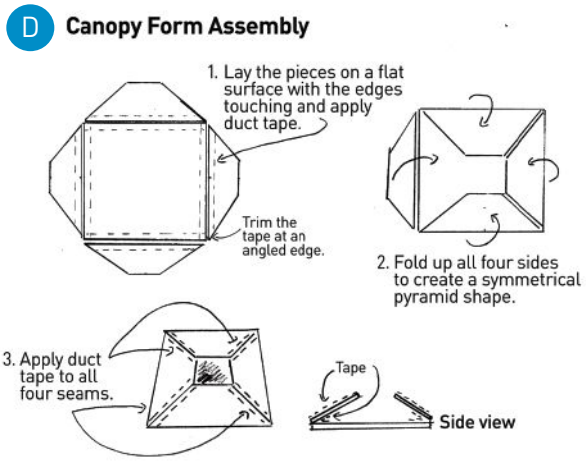
Starting with base/pedestal top form (Figures A and B), cut all pieces as indicated, then screw them together. I used 1½" screws to fasten the walls to the base, but 1" are probably fine. Note that you'll use this mold twice: for both the base and the pedestal top.

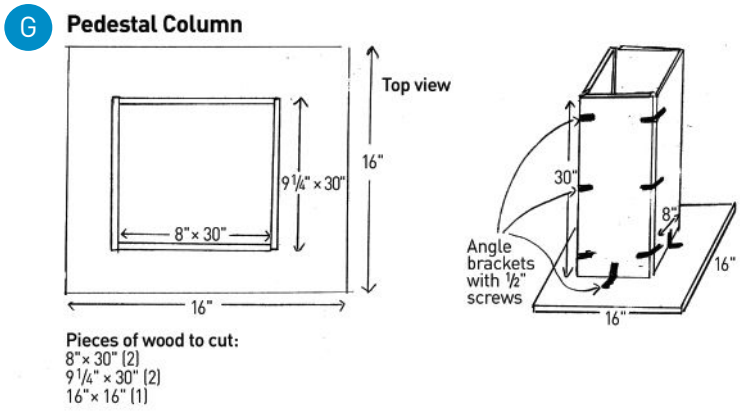
Next build the canopy form (Figures C, D, E, and F). Since this is a complex shape, it's a lot easier to use duct tape to hold the pieces together, and the shape of the form (a truncated pyramid) actually makes for a sturdy mold using just the tape.

Now build the column form (Figure G), which is a simple box shape, and next the cap form, which is a small piece, but is 2 forms built into one (Figures H, I, and J, following page).

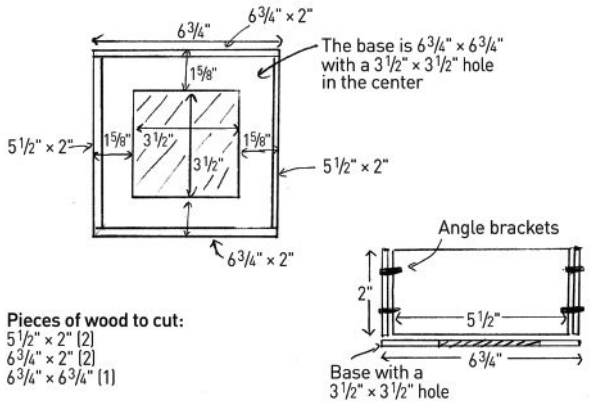






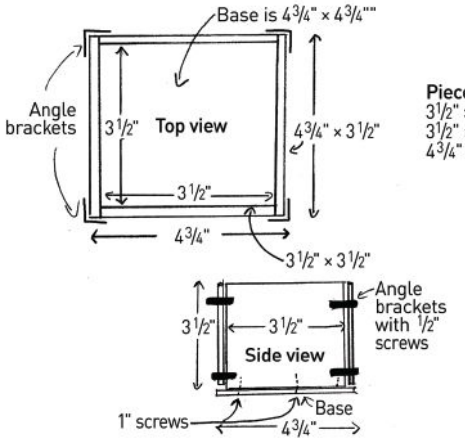


H Cap Bottom Piece Form



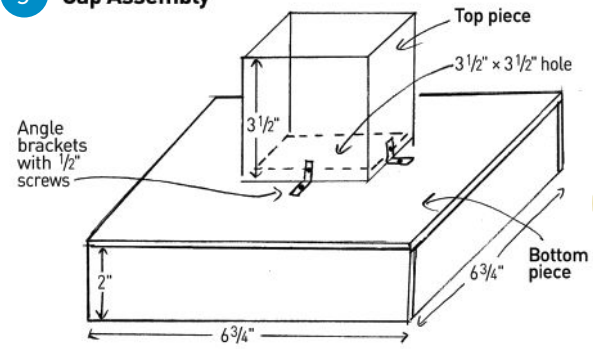
Pieces of wood to cut:
5½" × 2" (2)
6¾" × 2" (2)
6¾" × 6¾" (1)

I Cap Top Piece Form

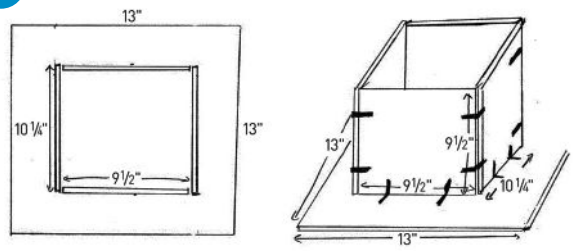


Pieces of wood to cut:
3½" × 3½" (2)
3½" × 4¾" (2)
4¾" × 4¾" (1)

J Cap Assembly

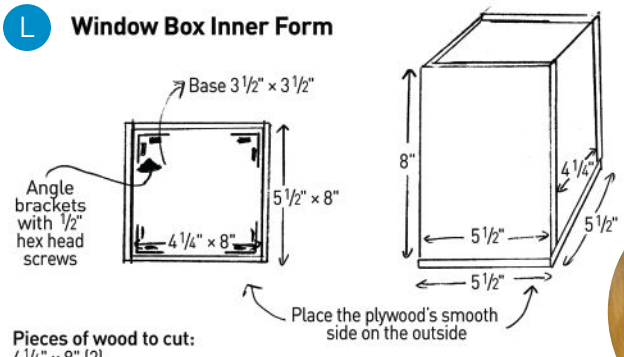


K Window Box Outer Form

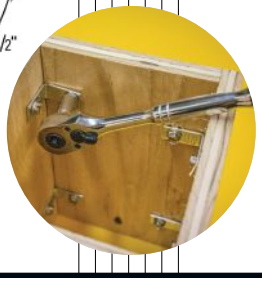


Pieces of wood to cut:
9½" × 9½" (2)
9½" × 10¼"" (2)
13" × 13" (1)

L Window Box Inner Form



Pieces of wood to cut:
4¼" × 8" (2)
5½" × 8" (2)
5½" × 5½" (1)



2. BUILD THE WINDOW BOX FORM

This form is trickier — it creates negative spaces inside the box to make the windows. The outer form is a simple box; the inner form is a smaller box with foam blocks duct-taped to each wall. Once the concrete has set, the foam blocks are removed to create the windows.

Build the outer and inner form boxes as shown (Figures K and L).

Cut out 10 pieces of 1" foam, each 5½" square. Using 2"-wide duct tape, attach 2 pieces together by wrapping tape around all 4 edges to make a 2"-thick block (Figure M). Repeat to make 4 more blocks.

Using more duct tape, attach one foam block to the bottom of the inner form. Then tape a block on each side, 2" up from the bottom (i.e., flush with the bottom of the plywood) (Figures N and O).

Insert the inner form inside the outer form (Figure P). Make sure it's a tight fit, otherwise it can float out of position when you pour the concrete. If it's too tight, use sandpaper to trim the foam blocks, or just remove one side of the outer box, insert the inner box, and then replace the outer panel. It's OK if the foam is compressed a little.

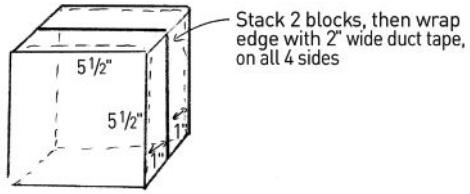
3. MIX A BATCH OF CONCRETE

I've found it's best to start with 4 parts concrete to one part water, and then add more water to get the consistency you want. In a plastic tub or bucket, measure out 4qts of concrete mix using a 1qt measuring cup. Then add 1qt of cold water, stirring until the mixture is completely dissolved (Figure Q). Now add a little water if needed, until it has the consistency of pancake batter.

Continue stirring for 5 minutes. I suggest you only mix batches about this size — any larger and it gets hard to stir, and trust me, you have a lot of stirring ahead of you!

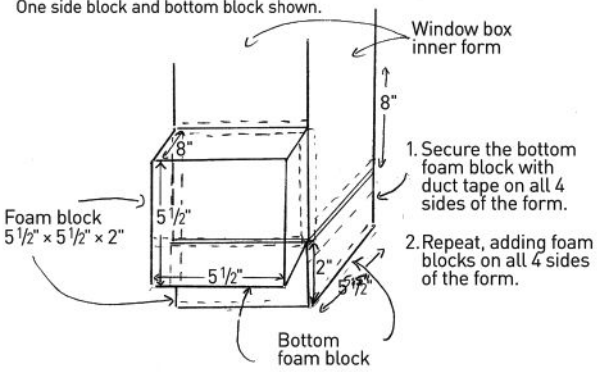
M **Foam Block Construction**

Cut eight 5 1/2" × 5 1/2" blocks from 1" thick stiff foam insulation



N **Window Box Inner Form Foam Block Assembly**

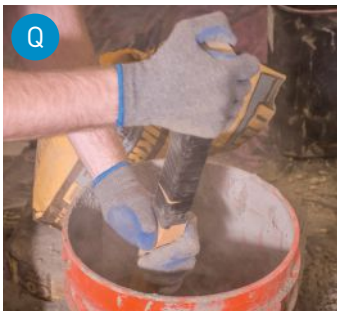
One side block and bottom block shown.



O

P

Q



4. POUR THE PEDESTAL AND CAP

Pour the concrete into the base/pedestal form until it's level with the top. Then pour into the cap form until it's level with the top edge (Figure R). Let both cure overnight, ideally 24 hours.

NOTE: Pour any leftover concrete into a heavy-duty plastic bag, and scrape as much off the tub as possible. Then use a garden hose outside to rinse the tub. Don't rinse in a sink until almost all the concrete is gone, or you run the risk of plugging up your sink drain with sand and concrete!

Before making any more pieces, check that the pedestal and cap have cured properly. Unscrew the pedestal form and carefully remove the side panels. You may have to pull hard to get the concrete to release from the plywood, but don't worry, it's not fragile. Save all the panels, as you're going to cast a second piece (the base) from the same form.

For the cap, carefully remove all the panels (Figure S). The piece with the square hole in it might be tricky to remove, if the top of the cap is wider than the hole. If needed, use a handsaw to cut this piece away (Figures T and U).

5. POUR THE BASE, COLUMN, AND CANOPY

Assuming both the pedestal and cap came out fine, move on to the other pieces.

Reassemble the base/pedestal form, and make another identical piece for the base.

The column is a big piece, so you'll need more than one bag of concrete. It's hard to mix that much concrete at the same time, so think in terms of 4 batches to fill up the form. Again, make sure it's level.

This piece will be particularly heavy, so if you're not that strong or don't have a friend to help, I suggest making the column shorter by just filling the form halfway. The lantern still looks great when shorter!

For the canopy, it's important that the concrete fill the entire form, especially the thin angled edges. Make the first batch a little thinner than usual so that it fills the whole cavity. Then you can go back to regular pancake-batter thickness. You may see some liquid concrete seep out corners; that's fine. It's more important that there are no air pockets. Give the whole thing a good shake, then fill the form all the away to the bottom edge of the square hole. Let it set for at least 24 hours — ideally 48 hours since this mixture is a little thinner (Figure V, following page).

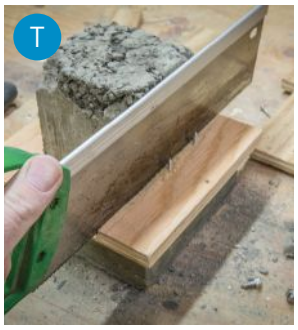
Then simply remove the duct tape and the panels should pull off (Figure W). If some of the edges come out a little rough, that's OK — in my experience people prefer the "rough" look.

IMPORTANT: Place your forms on a level surface before pouring concrete. If they're not level, the top surface of the piece you're casting will not be parallel with the bottom surface! Use a bubble level (or a level app on your smartphone) and shims if needed to level the form.

R

S

T



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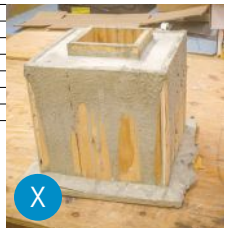
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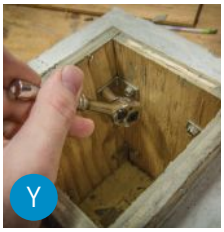
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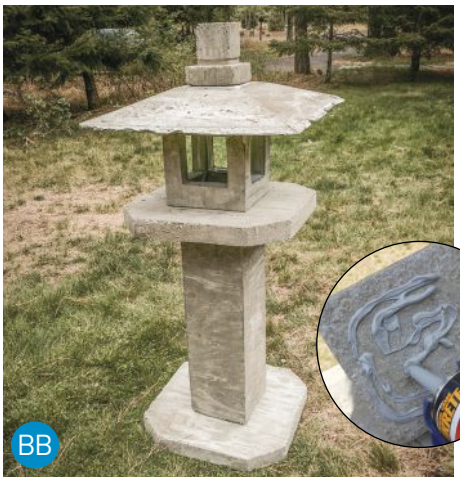
AA


BB


CC

6. POUR THE WINDOW BOX.
Now that you're a concrete expert, it's time to tackle the trickiest piece, the window box. This piece has some thinner sections, where regular quick-set concrete would likely crack. So you'll use a specific concrete called "construction grout" or "structural grout." Mix a normal-sized batch, about ⅓ of the 50lb bag. Once again since the cement needs to get into tight corners, make the mixture a little on the liquid side.

Pour into one corner and check that the mixture fills the bottom of all 4 corners; you can use a stick of 2×2 lumber to push the mixture down. Then fill all the sides, pouring directly into each side, until the mixture is level with the top edge (Figure X). Let it set at least 24 hours; 48 hours is best.

To remove the inner panels, use the small socket wrench to remove all the hex head screws, then gently wiggle out all 4 panels, starting with the narrower ones (Figure Y). Remove the outer panels with a screwdriver.

To remove the foam blocks, first drill a ½" hole in the foam near the corner of the block (Figure Z), then use a keyhole saw to cut out most of the foam. Peel off the duct tape, and you have a window! Do this on all 5 foam blocks and window box is done (Figure AA).

7. ASSEMBLE YOUR LANTERN
Each piece on its own is not that heavy (except for the column), but once assembled the lantern will be too heavy to move. So find the place where you want to put the lantern and move each piece separately to that location.

Don't just stack the pieces — it's important that you glue them together so that the lantern doesn't accidentally topple over and injure somebody! Use Quikrete Construction Adhesive or something equivalent. You'll be using a lot of glue, so cut the tip for wide diameter and fast flow.

First make sure the base is on solid ground and adjust it with small rocks or gravel until it is perfectly level in all directions. The rest of the pieces you can eyeball for level (or plumb, for the column).

To put the column on the base you'll need a helper! Once in position, adjust for level/plumb by adding bits of gravel under the column bottom. Then tilt the column slightly, apply the adhesive liberally, and tip the column back. Let dry for 24 hours.

Place the other pedestal on the column and let cure for 2 hours. Then proceed with gluing the window box. Then glue the canopy and cap (Figure BB). Your lantern is complete!

LIGHT IT UP

Of course you can make it a real lantern by adding a candle (Figure CC) or LED lights. Make your own tiny weatherproof LED lanterns at makezine.com/projects/eternal-flame-indestructible-led-lantern, or try Dark-Detecting LEDs at makezine.com/projects/dark-detecting-led.

To add permanent lighting, you might try gluing a length of pipe, ½" diameter or wider, into the center of the forms for the column and pedestal, to leave an open conduit for wiring.

GOING FURTHER

The variety of Japanese stone lanterns is amazing. Search online for styles you like, and then modify the forms I've provided to create your own design. Some ideas:

- Top it with a traditional jewel-in-the-lotus shape, by carving your own mold.
- Use an old satellite dish to cast an umbrella-shaped canopy; try a trash bag or nonstick cooking spray as a mold release.
- Create incised details or symbols on the column, by gluing raised shapes inside the mold. If you do 3D printing, let your imagination go wild!
- Add window frames. *Make:* engineering intern Matt Kelly built the beautiful wooden window frames shown here. Visit the project page at makezine.com/go/concrete-lantern to see how to make the frames, and to share your own designs.

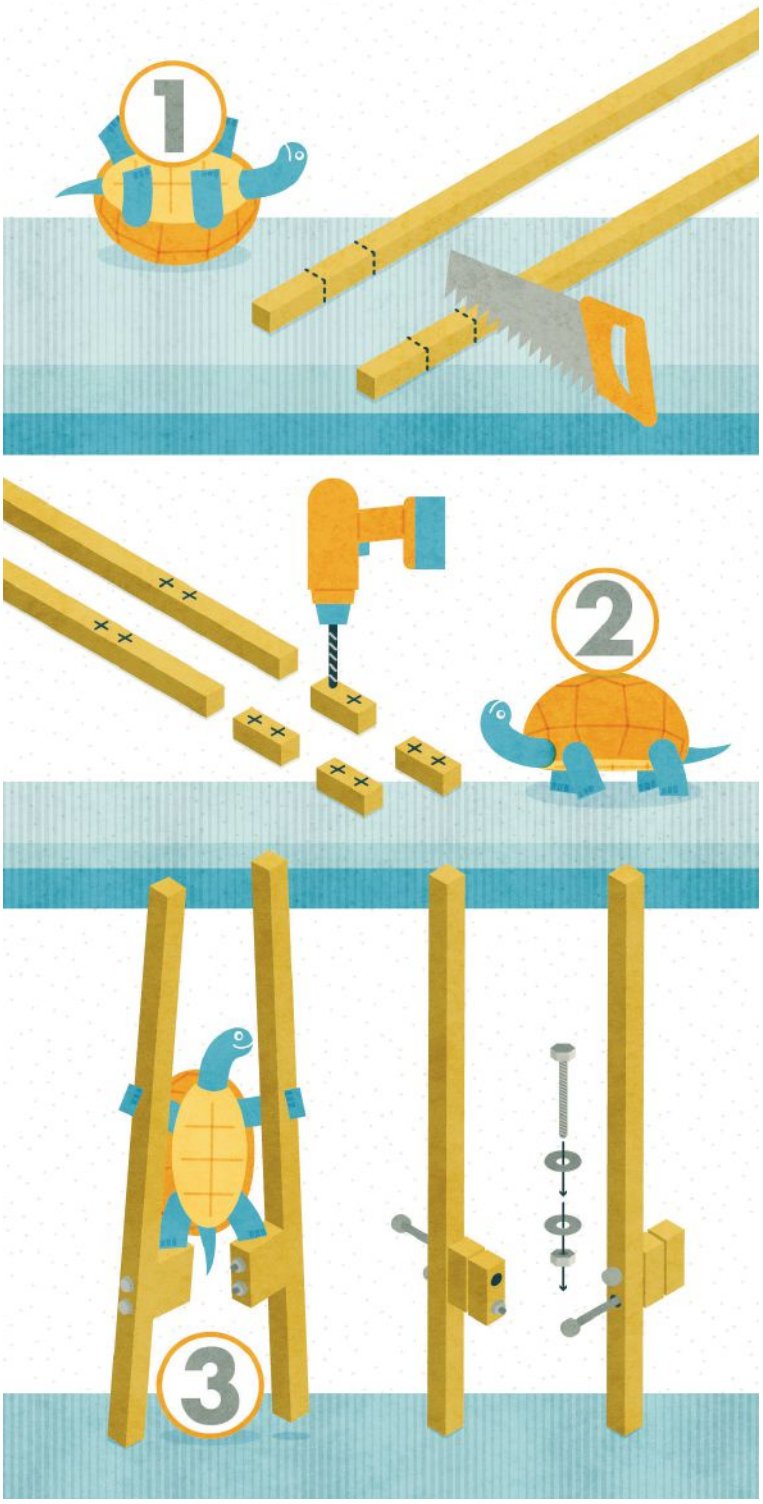
Building molds for concrete is really rewarding, and definitely not something most people do. Enjoy your lantern — it's one of those rare things that looks better as it gets older. And start thinking about other things you can make out of concrete!

See more photos, grab the full-size diagrams, and share your build at makezine.com/go/concrete-lantern.

Hep Svadja, Jim Becker, Matt Kelly

1-2-3 15-Minute Stilts

Written by Caleb Kraft ■ Illustrated by Andrew J. Nilsen



MANY OF US ENJOYED A PAIR OF STILTS IN OUR YOUTH, SO WHY STOP AS ADULTS? Here's how to make a simple pair of wooden stilts for someone of any age. Not only are they easily customizable, but they can literally be built in 15 minutes. You'll spend more time buying the materials than building these — and way more time having fun on your finished stilts.

The total cost of materials is under $20 and this entire project only requires 4 cuts and 12 drilled holes. Dress up your stilts any way you like — they can be a great addition to your Halloween costume.

1. MAKE YOUR 4 CUTS

From each piece of lumber, cut off 2 blocks both 3" long. This adds up to a total of 6" cut off each of your stilts.

2. DRILL HOLES

Measure and mark all 4 blocks for drilling 2 bolt holes. Spacing the bolts 1" apart is perfect.

For the long pieces, you'll need to decide how high off the ground you wish your feet to be. For my stilts, I placed the foot at 12" off the ground. This means that my top bolt hole was 11" from the bottom of the stilt.

If you have a vise that you can clamp them into, you can drill through all 3 pieces at the same time. This isn't necessary though.

3. ASSEMBLE STILTS

Thread the bolts through the holes, with a washer on each side. Add the nuts, and tighten.

Now you can walk around on your super simple stilts. It may take a little practice to get perfect!

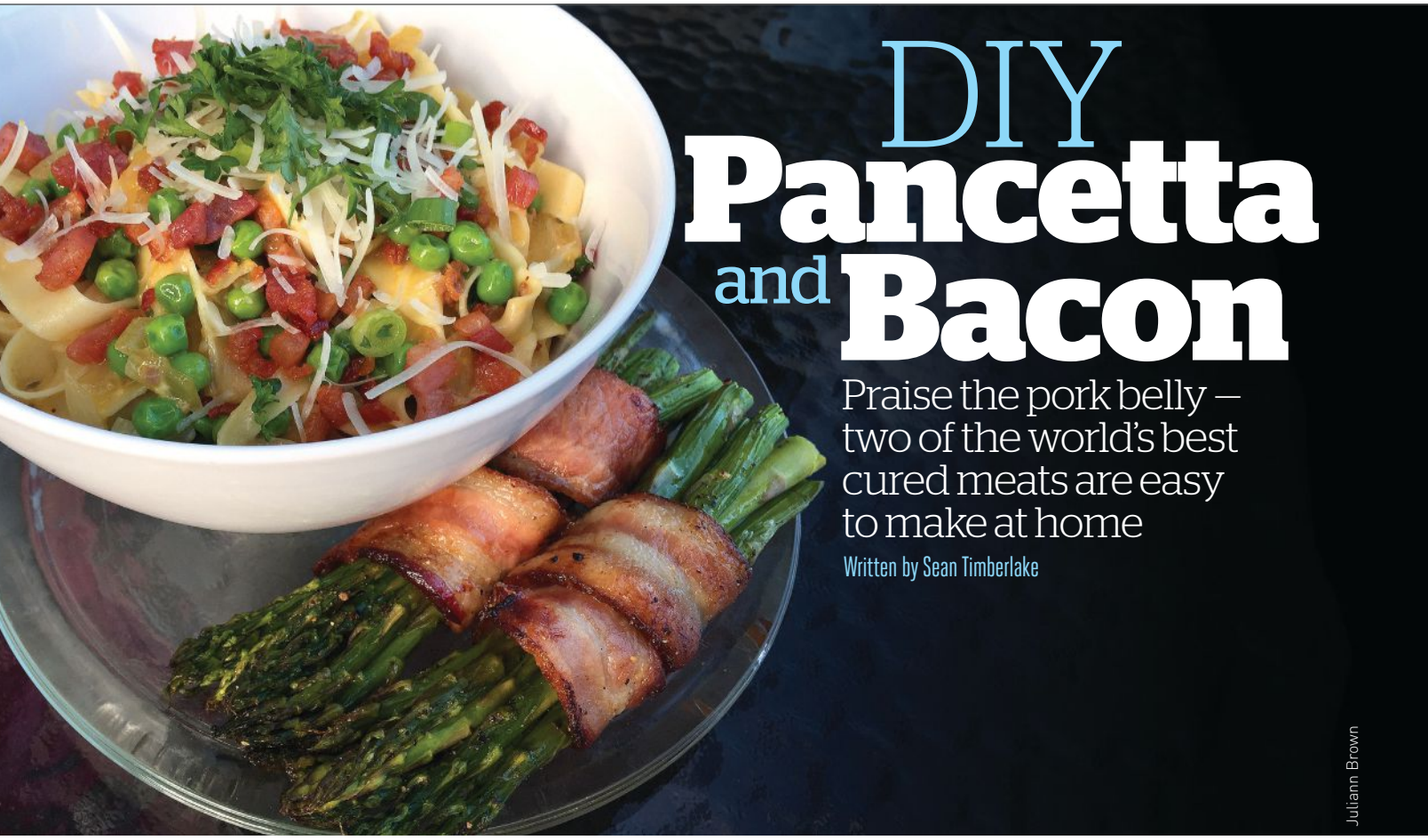
CALEB KRAFT is Senior Editor for *Make:*. He gets ridiculously excited seeing people make things, and his favorite thing in the world is sharing the hard work of a Maker.

Time Required:
15 Minutes
Cost:
$10–$20

You will need:

- **Lumber, 2×2, 8' lengths (2)** Fun fact: nominal 2×2 lumber actually measures about 1½"×1½".
- **Bolts, 5"-6" long (4)**
- **Washers (8)**
- **Nuts (4)**
- **Saw**
- **Drill and bit** a little bigger than your bolts
- **Marker**
- **Vise (optional)**

Share your stilts at makezine.com/go/15-minute-stilts



DIY Pancetta and Bacon

Praise the pork belly — two of the world's best cured meats are easy to make at home

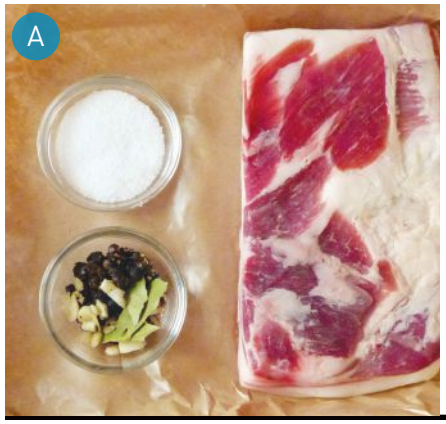
Written by Sean Timberlake

Juliann Brown

Time Required: 1-3 Weeks
Cost: $20-$40

EVERYTHING'S BETTER WITH BACON, AND IT'S A PRETTY SIMPLE MATTER TO MAKE YOUR OWN. Bacon and its Italian counterpart pancetta are fundamental members of the expansive world of cured meats. At their most basic, they require just three ingredients — meat, salt, and time — plus a little woodsmoke for bacon. But there's plenty of room to get fancy.

SEAN TIMBERLAKE founded Punk Domestics in 2010, a curated site for the DIY food community. He is the Food Preservation Expert for About.com, and has maintained the blog Hedonia since 2006. He lives in San Francisco with his husband and their hyperactive terrier, Reese.



PANCETTA

INGREDIENTS:

- **3lbs pork belly**
- **1½ oz kosher or sea salt**
- **1½ tsp black peppercorn, crushed**
- **1½ tsp juniper berry**
- **3 cloves garlic, crushed**
- **3 bay leaves**
- **Sprig of rosemary**
- **Cheesecloth**
- **Butcher's twine (cotton)**

Pancetta is the simplest to make. Think of it as the gateway drug to making bacon. It's a meat that is lightly cured, but brings big, porky flavor to classic Italian dishes like pasta carbonara or all' amatriciana.

Head to your preferred butcher, and purchase a slab of quality pork belly. (Pro tip: If you can find hog jowls instead of belly, you will make guanciale, which is even better.) How much is entirely up to you; personally, I go in for about 3 pounds per batch.

1. WEIGH

Get an accurate weight on the slab, because you want a 3% ratio of salt to meat to get a good cure. For this reason, I usually weigh in metric; for 1kg of belly I would weigh out 30g of salt. If you're unwaveringly American, that's ½ ounce of salt per pound of meat.

2. TRIM AND SALT

Trim the belly so it's a nice, even shape (Figure A). You can remove the skin or leave it on. Lay the meat on a sheet of cling wrap on a sheet pan. Mix the salt and spices, and rub it all over the belly. Wrap tightly in a few layers of cling wrap, making sure the cure is in contact with all the meat (Figure B).

3. CURE

Keep in the refrigerator on the sheet pan for 5 days, turning daily. The belly will release some liquid; this is normal.

Sean Timberlake

4. RINSE AND DRY
On the fifth day, unwrap, rinse, and pat dry. Your pancetta can now be cut and cooked.

5. HANG (DRY CURE)
You can intensify the flavor by hanging the pancetta, and even turn it into a cured meat that can be eaten uncooked.

Wrap the pancetta in 3 layers of cheesecloth. Truss the pancetta with butcher's twine, creating loops on about 1" intervals (Figure C). Hang the pancetta in a cool, dark place for 3 weeks or more. The ideal curing temperature is around 55°F, with humidity at 70–75%, but you can get perfectly satisfactory results by hanging it in a basement or any other cool place in the house.

Remember when you got that initial weight? Continue to weigh your pancetta as it cures. In order to be consumed as an uncooked cured meat, it must lose at least 30% of its weight (another reason I weigh in metric). When it's ready, the flesh should feel evenly firm, not squishy in the center.

6. UNWRAP
When you unwrap the pancetta, you may see mold. Fuzzy, white mold is in fact a good thing; it's harmless, and you can wash it off with vinegar. Ditto green mold. If you see red or black mold, however, you're in the danger zone, and the pancetta must be tossed. (This is unlikely unless you had it in an exceedingly humid environment.)

7. ENJOY
Your cured pancetta can be refrigerated, wrapped in paper, for up to 1 week, or frozen for up to 3 months.

• • •

BACON

INGREDIENTS:
- **3lbs–4lbs pork belly**
- **1lb kosher or sea salt**
- **8 tsp sodium nitrite**
- **8 oz granulated sugar**

America's favorite pig product differs from pancetta in a few key ways. First, the cure typically has sodium nitrite, which, aside from deterring *Clostridium botulinum* spores, gives bacon its signature pink color and faintly tangy flavor. It's also often sweet rather than savory. Finally, bacon is smoked.

Sodium nitrite is sold as Prague Powder or Instacure #1, and is often referred to as "pink salt." (Don't confuse it with Himalayan pink salt or similar naturally occurring salts.)

TIP: If you're concerned about nitrate consumption, you could omit the pink salt. The resulting product will still be good, but will lack the signature flavor of classic American bacon. In my opinion it's better to simply enjoy bacon in moderation.

1. TRIM AND SALT
Make a cure by mixing the salt, pink salt (nitrite), and sugar. This is enough for more than one slab, and can be stored in a sealed container in a cool, dry place indefinitely.

Again, trim the pork belly to an even shape. Lay ¼ cup of the cure on a sheet pan, and dredge the belly on all sides (Figure D).

Place the belly in a large zip-top bag and add the remaining cure from the sheet pan. You can also add flavors such as ¼ cup of maple syrup, and a shot or two of bourbon. Remove air and seal tightly (Figure E).

2. CURE
Place the bag in a container, and keep it in the refrigerator, turning daily to redistribute the juices and infuse the bacon with flavor.

On the fifth day, give the belly a poke. If it's still a little squishy, keep curing it. If it's firm at the thickest parts, it's ready to smoke.

3. RINSE AND DRY
Rinse the belly and pat dry with paper towels. Lay it on a rack, on a sheet pan lined with paper towels, and set a fan on low to blow air over the meat for a few hours (Figure F). Or, you can just leave it on the rack in the refrigerator for 1–3 days.

The goal here is to create what's called the *pellicule*. This is a tacky layer of proteins on the surface that will bond with smoke, creating deliciousness.

4. SMOKE
Preheat a smoker to 200°F. When the meat is just lightly sticky to the touch, place it in the smoker, on a rack over a drippings pan.

The bacon is ready when it reaches an internal temperature of 150°F (Figure G). Remove and let cool. If you left the skin on, wait until it's just cool enough to touch, then carefully trim it away with a sharp knife.

5. ENJOY
Like pancetta, bacon will keep a week in the fridge and 3 months in the freezer. But, realistically, it will get used much faster than that.

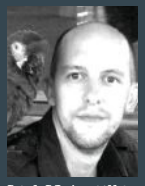
See more photos and share your curing tips and tricks at makezine.com/go/pancetta-and-bacon.

Time Required:
A Weekend
Cost:
$350–$400

Written by Dan Royer

DIY Jumbotron LED Wall

Because who doesn't want a giant LED video screen?



DAN ROYER is the malevolent force lurking under Marginally Clever Robots, Ltd. He's still trying to send his robots to the moon.

A

IT'S A GIANT DIY TV! WHEN YOU'RE DONE BUILDING IT, MAKING THE LIGHTS DO WHAT YOU WANT IS AS EASY AS EDITING A VIDEO — no coding required! Hang your LED screen on a wall, or take it to your next outdoor festival and blow people's minds.

I've written open source code to upload any video from anywhere to your new LED wall. All you have to do is put it together. The Teensy microcontroller from PJRC, paired with their OctoWS2811 shield, makes controlling lots of LEDs really easy using the Arduino programming environment.

This project, when completed, measures more than 2m (6') wide, so it is best done with a friend.

1. READ THROUGH THESE STEPS

Knowledge is power!

2. COLLECT ALL THE PARTS

I'm happy to sell you a box full of LEDs and electronics (Figure A) if that will simplify your life.

3. CONNECT TEENSY AND OCTO SHIELD

Solder the headers onto your Teensy and then attach your OctoWS2811 Adaptor (Figure B). The Teensy will receive video from your PC and then transform it into the language of LEDs.

4. SOLDER POWER CONNECTORS TO LEDS

Solder a male T-connector (Figure C) to each LED strip, and a female T-connector to only 18 of the strips. Arrows on the strip point to the female end; power goes in at the male end (Figure D) and out at the female. The strips will alternate direction in a zigzag pattern so power can pass

through 2 at a time (and data 12 at a time). So be consistent about your wire colors! Switching in the middle would break the Ghostbusters Rule (don't cross the streams).

5. PREPARE THE DATA CABLE

Strip 12" from one end of the CAT5 cable to expose the 4 wire pairs inside (Figure E).

The female JST SM connector has 3 wires: white, green, and red. The red one's not used here. Solder the green one to the orange CAT5 wire, and solder the white one to the orange/white CAT5 wire. Now you have a CAT5 cable that has RJ45 on one end and a SM connector on the other.

Solder female SM connectors to 2 more exposed pairs: blue and blue/white, and green and green/white (Figure F). The brown and brown/white pair is not used. Double-check your work — and label both ends so you can sort them later.

6. PREPARE THE POWER CABLES

One CAT5 cable can power 8 LED strips, so you'll need all of 4 cables and some of a fifth cable. They're all prepared the same. Take one 9'-long CAT5 cable and expose the wire pairs at both ends. One solid colored CAT5 wire will connect to one red power wire on an LED strip. The white CAT5 wire will connect to the white power wire on the LED strip.

We soldered female T-connectors here too, so we could unplug the wires.

7. SEW THE VELCRO (OPTIONAL)

We sewed a velcro border on the back of the fabric (Figure G), so we could easily dismantle and roll up the LED wall. You can use the velcro to mount it to a wall or a stand-alone frame.

8. MOUNT THE LED STRIPS

Lay the fabric flat on the floor. Lay the first strip at the "top" of the wall with the male end on the left (arrows pointing to the right), and stick it down using its adhesive backing (extra glue won't hurt). Lay strip 2 below the first one, with arrows pointing left. Repeat for all 36 LED strips (Figure H). We used masking tape with measured marks to make sure our strips were evenly spaced.

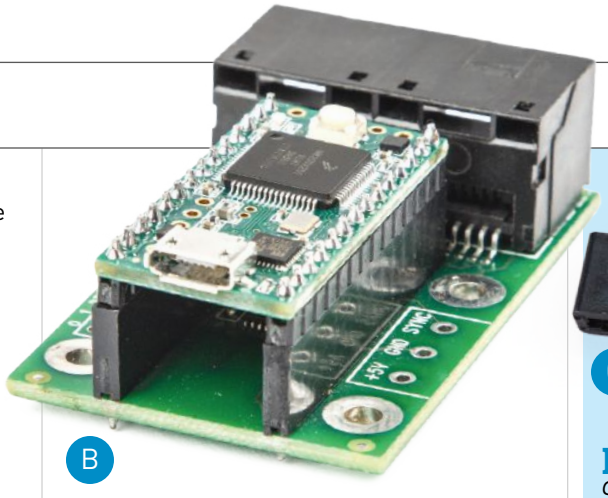
9. CONNECT POWER

Follow the power wiring diagram (Figure I, following page) to connect power to every second strip. On the left side, connect every odd strip (1, 3, 5, etc.) to a power cable. On the right side, connect strip 1 to 2, then 3 to 4, etc., all the way down.

Each power cable then connects to a power supply — solid colors to VCC, white wires to GND.

10. CONNECT DATA

You'll connect the data cables in 12-strip blocks (Figure J). Connect Data line 1 (orange and orange/white) to the first LED strip's male SM connector. Then connect the next 11 strips, zigzagging, down through strip 12. Connect Data line 2 (blue and blue/ white) to strip 13's male SM connector, zigzagging down through strip 24. Connect Data line 3 (green and green/white) to strip 25's male SM connector, zigzagging through strip 36.



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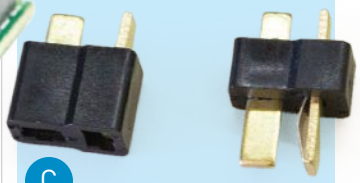
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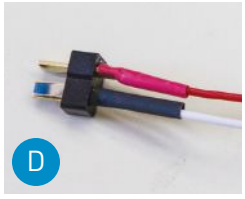
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E


F


G


H

Materials

Get a kit with both boards, the LEDs, and power supplies from marginallyclever.com, or buy the following materials separately:

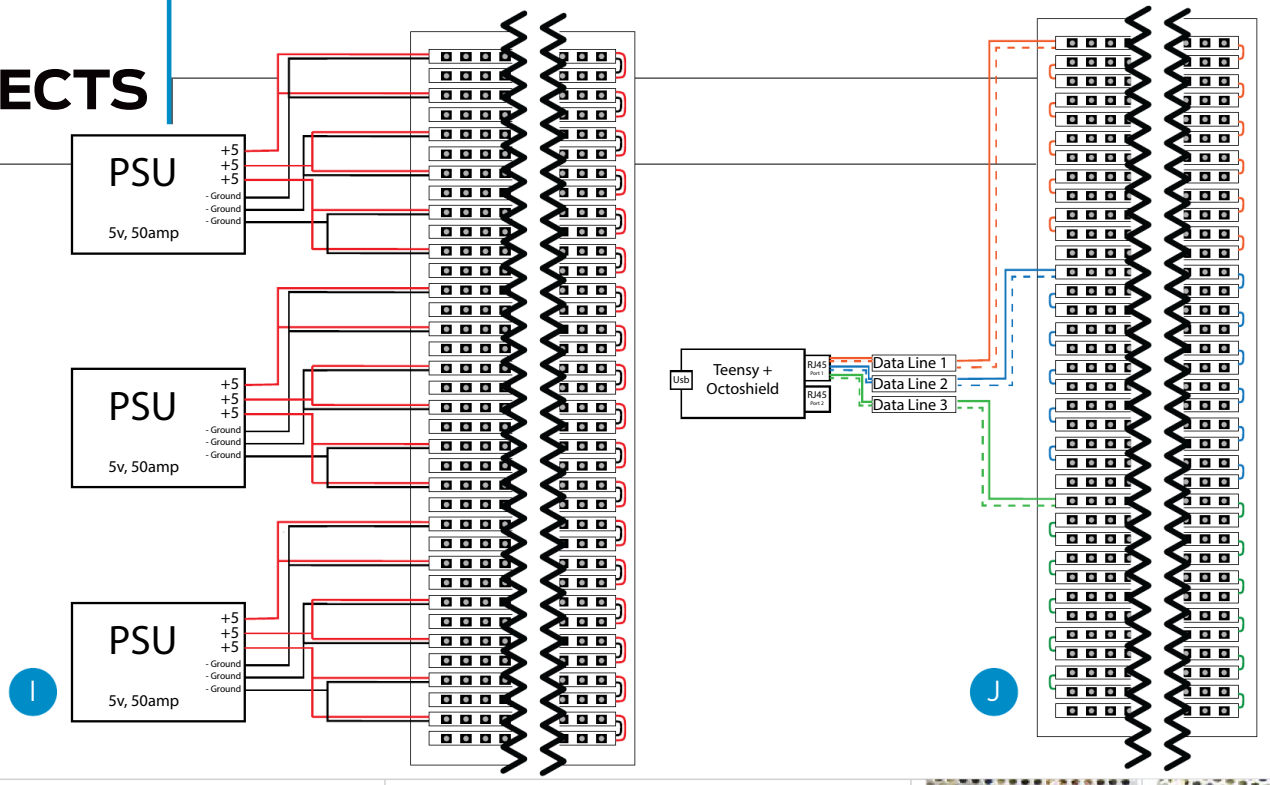
- **Teensy 3.1 microcontroller board** from pjrc.com/store/teensy31.html
- **OctoWS2811 Adaptor board** pjrc.com/store/octo28_adaptor.html, aka "Octo shield"
- **RGB LED strips, WS2812B type, 64 per strip, 30 per meter, with black backing, self-adhesive (36)** Includes 3-pin JST SM connectors on both ends for data, and a red/white pair for power. It's wise to get at least one spare strip.
- **Power supplies, 5V 50A (3)**
- **Black vinyl cloth, at least 56"×90½"** We cut ours with 11" excess all around.
- **PC power cables (3)**
- **Power T-connectors, 2-pin: male (36) and female (36)**
- **CAT5 cable, about 45'** cut into 5 lengths about 9' each
- **CAT5 cable with at least one RJ45 connector, about 9' length**
- **JST SM connectors, 3-pin (3)** or 39, if your LED strips don't already have them
- **Heat-shrink tubing, red and black, about 5' each**
- **Hook-and-loop tape, about 33' total length (optional)** aka velcro tape

TOOLS

- **Computer with the following software:**
  - **Arduino IDE version 1.6.3** Free download from arduino.cc/downloads. Versions 1.0.6, 1.6.1, and 1.6.5 also work; current version 1.6.6 does not yet support the Teensyduino plugin.
  - **Teensyduino plugin for Arduino** free from pjrc.com/teensy/td_download.html
  - **Processing** free from processing.org; to send video from your computer
- **Screwdrivers** for connectors
- **Soldering iron**
- **Wire strippers**
- **Crimper for T-connectors**
- **Sewing machine (optional)**

Hep Svadja

Dan Royer, Hep Svadja



Now plug the data cable's CAT5 connector into the Octo shield's port 1.

11. WIRE THE POWER SUPPLIES

Cut the end off the three PC power cables, strip the wires, and connect them to the power supplies (Figure K). Remember that black goes to (L) Live, white to (N) Neutral, and green to Earth (ground).

We found it easiest to use a power splitter so that one switch could control the whole wall.

12. PROGRAM THE TEENSY

Download the Arduino sketch for the Teensy from Github (github.com/i-make-robots/ledwall/tree/64x36-wall), then upload it to the board using the Arduino IDE. When the Teensy reboots and you turn on the LED wall power, it should display a test pattern (Figure L). If not, check your power connections and the Octo shield connection.

13. TEST YOUR JUMBOTRON!

Grab the Processing sketch from Github too, and run it on your computer. A section of your screen should appear on the LED wall. Move your video program into that part of your screen and hit Play (Figure M). Turn your speakers way up. Make popcorn, turn off the lights, and enjoy.

14. SHOW US WHAT YOU GOT Tweet your finished wall to @marginallyc and @make!

USING YOUR DIY JUMBOTRON

» **COLOR QUALITY** You might see some discoloration in the 12th strip. This is because the data and power lines are long. Try doubling the number of data lines. or get bigger power supplies.

» **VIDEO SYNC** The Processing sketch on the PC sends one 3-byte RGB pixel (24 bits) to the Teensy for each RGB LED, from top left to bottom right. But occasionally these messages never arrive. Over time, this can make the video really weird.

To fix this, the PC uses color `000` as a frame marker, which tells the Teensy "I'm done sending this frame, show it and we'll start the next one." To ensure that color `000` never happens at the wrong time, Processing adjusts each pixel so that a 0 in any color channel becomes a 1.

» **AUDIO SYNC** If your computer is slow, the video on the LED wall will lag behind the sound in your movie. You can easily adjust the audio delay by using VLC media player (videolan.org/vlc). The Processing sketch is the bottleneck — you could also try a faster computer or try optimizing the OctoWS2811 code (learn more at pjrc.com/teensy/td_libs_OctoWS2811.html) to run the video faster.

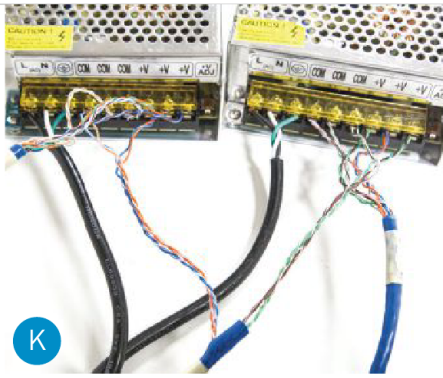
» **BREAK THE GRID** The LEDs don't have to be a grid — they could be wrapped around a piece of art, or a car, or hung across the ceiling.

» **USE A DIFFUSER** Jumbotrons are best viewed from a distance. Diffusion can blur the pixels a little so the brain has an easier time seeing the picture. Try hanging a bedsheet in front of the LEDs (Figure N).

» **SELFIETRON** Use the camera on your laptop as the video source for the Processing sketch.

» **NEXT LEVEL** Replace the Processing sketch with your own. Build a classic video game and add a joystick?

Show us your LED wall and see more photos at makezine.com/go/diy-jumbotron-led-wall.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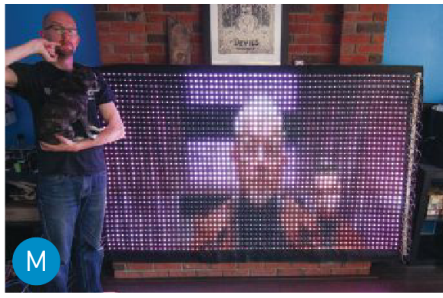
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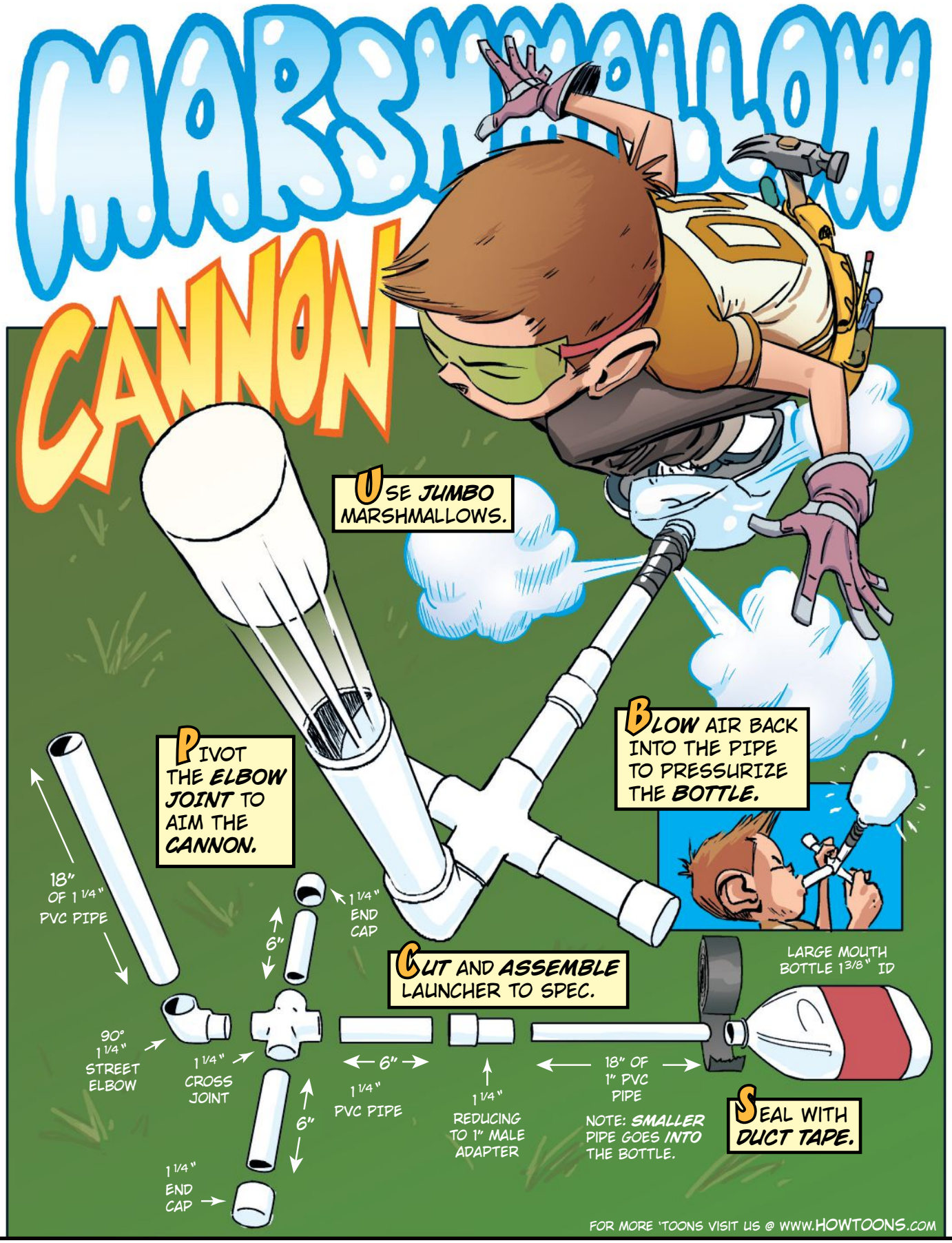
Dan Royer, Hep Svadja


MARSHMALLOW
CANNON
USE JUMBO MARSHMALLOWS.
PIVOT THE ELBOW JOINT TO AIM THE CANNON.
BLOW AIR BACK INTO THE PIPE TO PRESSURIZE THE BOTTLE.
CUT AND ASSEMBLE LAUNCHER TO SPEC.
SEAL WITH DUCT TAPE.
18" OF 1 1/4" PVC PIPE
1 1/4" END CAP
6"
90° 1 1/4" STREET ELBOW
1 1/4" CROSS JOINT
6"
1 1/4" END CAP
6"
1 1/4" PVC PIPE
1 1/4" REDUCING TO 1" MALE ADAPTER
18" OF 1" PVC PIPE
NOTE: SMALLER PIPE GOES INTO THE BOTTLE.
LARGE MOUTH BOTTLE 1 3/8" ID
FOR MORE 'TOONS VISIT US @ WWW.HOWTOONS.COM

NATHAN SEIDLE is the founder and CEO of SparkFun Electronics in Boulder, Colorado. Nathan founded SparkFun in 2003 while an undergraduate student studying electrical engineering.

High-Tech Honey

Enable a beehive to track its weight, humidity, temperature, and battery voltage online

Written by Nathan Seidle

Time Required:
A Few Weekends
Cost:
$250–$350

Materials

- **Particle Photon Wi-Fi development kit,** store.particle.io
- **Arduino Uno,** makershed.com
- **Load cell amplifier breakout board HX711,** sparkfun.com
- **Package scale, 200kg**
- **Antenna, 2.4GHz U.FL adhesive**
- **LiPo battery, 6Ahr**
- **Solar cell, large**
- **Humidity and temperature sensor** HTU21D type
- **Tape, teflon (PTFE)**
- **Breadboard**
- **Maximum power point (MPP) solar charger**
- **Enclosure, outdoor**

ON A VISIT TO PORTLAND, OREGON LAST SUMMER MY FRIEND MENTIONED HE HAD ALWAYS WANTED TO PUT A LOAD CELL UNDER A BEEHIVE to measure the weight of the hive over time. After 9 months of testing and development, here's the story of how we did so to get live bee data.

PLEASE JUST STEP ON THE SCALE

A healthy hive can hit 400lbs (180kg) so we needed to create a scale that can handle the hive's maximum weight and also have the robustness to survive in the field.

There are a variety of 200kg bathroom and package scales available. The vast majority use four strain gauges A (one in each corner) that are wired in a Wheatstone bridge configuration B to create what's called a load cell.

This configuration of four gauges allows for low-cost voltage measurement instruments to measure a very minute change in resistance. To convert this voltage change to a digital reading for my Arduino, SparkFun has a breakout board C for the HX711 chip D commonly used in most consumer scales.

Adapting the scale also meant accounting for "creep." This means when you put a 12 pack of soda on your scale the reading will change the longer the weight is on it. A lot. For low-end human or postal scales this is fine. No one stands on the scale for more than a few seconds. But I planned to leave the scale in place for months on end.

What I learned is that calibration takes time.

Nathan Seidle and Lara Boudreaux

Expect to throw lots of known weight on your scale for days at a time to get the calibration points you'll need.

GETTING DATA TO THE INTERNET (OF THINGS)

With the scale mostly under control I moved on to getting the data from the field to a place where it could be stored and accessed easily. There are a handful of data storage services on the internet, but I went with my company's open source software, Phant.

I chose the Particle Core E to move my Arduino data online because I had one handy. In hindsight, a Particle Photon or SparkFun Thing would work just as well. With a few basic function calls I was moving weight data online from the Core to Phant.

Adding humidity and temperature to the system was cheap and easy thanks to the I2C-based HTU21D breakout sensor board F. I covered the board in teflon tape, protecting the sensor (in theory; in practice not so much) from pollen, bee feet, etc.

Because this system would be solar and battery powered, I added a voltage divider to measure the voltage on the battery through the analog-to-digital converter on the Core. A 2.5W solar cell G charges a 6 amp-hour LiPo battery H through the Maximum Power Point solar charger I. The LiPo battery will float between 3.6V and 4.2V and the system regulates this down to a clean 3.3V.

In my setup, the Core sends a trigger character to the Arduino J and the Arduino pulls a comma delimited weight, timestamp, and board temperature from the sensors and sends it back to the Core for uploading. An external 2.4GHz antenna K is connected over U.FL to the Core in order to increase the transmission range.

DATA ANALYSIS

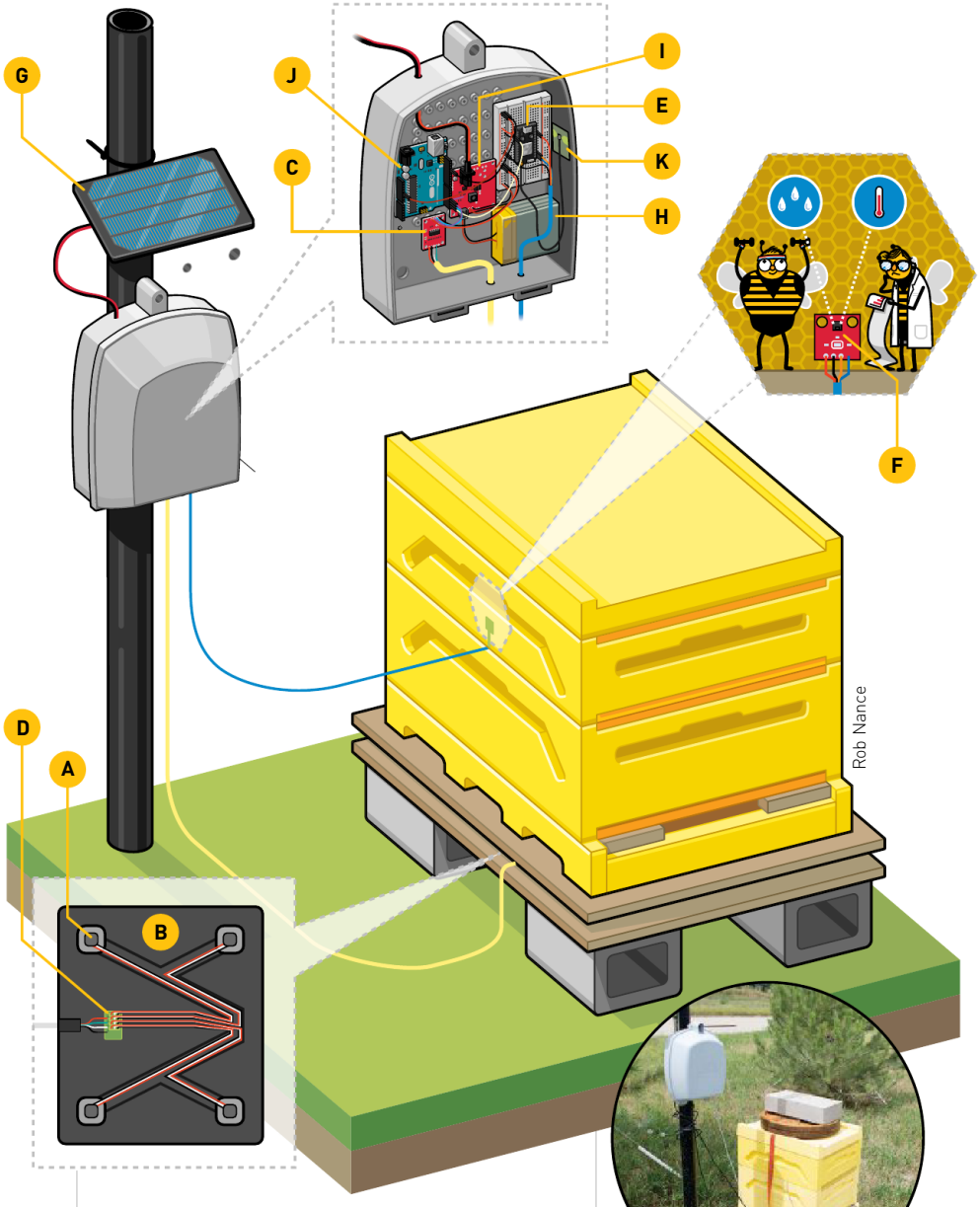
The folks at analog.io have made it easy to link a data stream and graph the various bits. Here's beehive weight (Figure 1) graphed over 6 days. We can see the bees leave at 6:20 every morning like clockwork. The hive loses many pounds of bees in a few minutes only to have them slowly return over the day.

In the second graph (Figure 2) we can see weight, temperature, and humidity over a few days. It's astonishing to see the bees depart in the morning at the precise ti me the ambient humidity dropped and temperature rose.

During a Colorado summer the ambient temperature swings from the 50s at night to 90s during the day. But the second graph reveals that the internal nighttime temperature of the hive hovers around 90°. This is astonishing! Outside Mother Nature is wreaking havoc but inside the hive the bees are doing a fabulous job of keeping things normal.

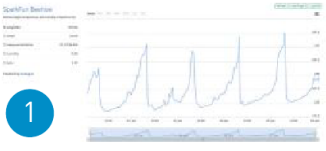
Overall, the project was a wild success. I highly recommend finding a friend who can safely show you around a beehive. It is wonderful getting a chance to see the bees in action.

Learn more about this connected beehive by visiting makezine.com/go/connected-hive.



Rob Nance

The outdoor enclosure, electronics, and solar cell are mounted to a pole near the hive. One wire runs to the scale underneath while another runs into the hive connected to the humidity and temperature sensor.



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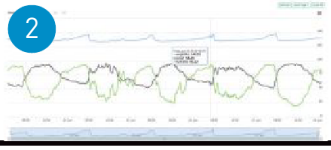


2

A Flood of Thoughts

Written by Dylan Rush

Modify a mannequin to print random musings from Reddit

Time Required: 3–6 Hours
Cost: $100–$120

DYLAN RUSH is a hobbyist inventor and professional software developer. He seeks to create thought-provoking art through engineering.

Hep Svadja

THE ONLY THING THAT'S EASIER DONE THAN SAID IS DOING NOTHING ... TRAFFIC IS LIKE ONE BIG PARADE, BUT NO ONE'S HAVING FUN ... TRAVELING SALESMEN ARE BASICALLY REAL-LIFE SPAM ...

With the press of a button, this mannequin delivers an amusing thought from its onboard thermal printer. These quotes are pulled from random post titles on Reddit's popular Shower Thoughts page (reddit.com/r/showerthoughts), where people share all those ideas or philosophical questions that race through their heads during those uninterrupted moments in the shower. An Arduino plucks the relevant data and downloads it over a Wi-Fi connection, resulting in an objet d'art that can surprise you with its cleverness.

1. HEAD SURGERY

Drill two holes in the back of the mannequin near the base, one for a pushbutton and one for the female power jack. Measure, mark, and cut a rectangle section out of the head to fit the thermal printer. Guide the wires through to the bottom, connect them to the printer, and place the printer into the section you've removed.

2. ASSEMBLE THE ELECTRONICS

Set up your breadboard using Figure B as a guide. Power comes from the 9V jack in the back of the mannequin head and travels down the left power rails of the breadboard. Using a 9V 2A power supply for this project is critically important for its success.

The small, red, logic level converter bridges the two halves of the breadboard, separately managing 5V on the left (supplied by the Arduino) and 3.3V on the right for the ESP8266 Wi-Fi board. Be careful to orient the logic level converter so that the 5V HV connections are on the left and 3.3V LV connections face right. Place a 1K resistor on the breadboard as shown, running from LV on the logic level converter board to a free row that we'll connect to the ESP8266 in the next step.

3. WIRE THE ESP8266

The ESP8266 is a great, inexpensive Wi-Fi board, but its I/O pins are not labeled. Use Figure A to reference the board's pinout.

The ESP8266 runs its default firmware in this project, so there's no need to program it. You will need to wire it, however.

Using the breadboard, connect the pins of the ESP8266 to the logic level converter as follows:

- RX to LV1 (**gray** wire)
- TX to LV2 (**brown** wire)
- VCC to LV (**purple** wire)
- GND to GND (**black** wire)
- CH_PD to breadboard row containing the free end of the resistor leading to LV (**blue** wire)

4. WIRE THE ARDUINO

To get the ESP8266 and the Arduino Mega talking to each other, connect HV1 from the logic level converter to TX1 on the Arduino, HV2 to RX1.

The momentary pushbutton is used to generate "new thoughts" to be printed. Connect one of the two leads from your pushbutton to D7 on the Arduino. Connect the other lead to any ground location on the breadboard. While you're at it, be sure to also ground the Arduino by running any of its GND pins to a ground rail on the breadboard.

To wire the thermal printer's serial connection, run its yellow cable to D6 on the Arduino and green to D5. Power the printer by running its red and black cables to their respective slots on the left (9V) power rail of the breadboard.

5. PROGRAM ARDUINO

Download the code for the Arduino by visiting the online project page at makezine.com/go/shower-thoughts. Open the code on your computer using the Arduino IDE software and update it with your own Wi-Fi SSID and password.

Next, go to Sketch → Include Library → Manage Libraries and find and install the Adafruit Thermal Printer Library. Connect your Arduino to your computer using a USB cable and upload the code to your board.

At this point your project should be functional once you connect the 9V 2A power supply to the female power jack. If everything is working smoothly and your shower thoughts are printing when you push the button, finish up by stuffing all of the electronics into the mannequin.

GOING FURTHER

The source code can be adapted to read data from anywhere on the internet or your home network. Print weather, tweets, even breaking news. And then take it to the next level by adding a text-to-voice adapter and a sorcerer's cap to turn your mannequin head into a wisdom-speaking wizard.

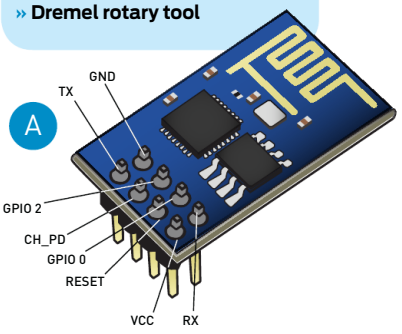
Download the code and view detailed schematics for this project over at makezine.com/go/shower-thoughts.

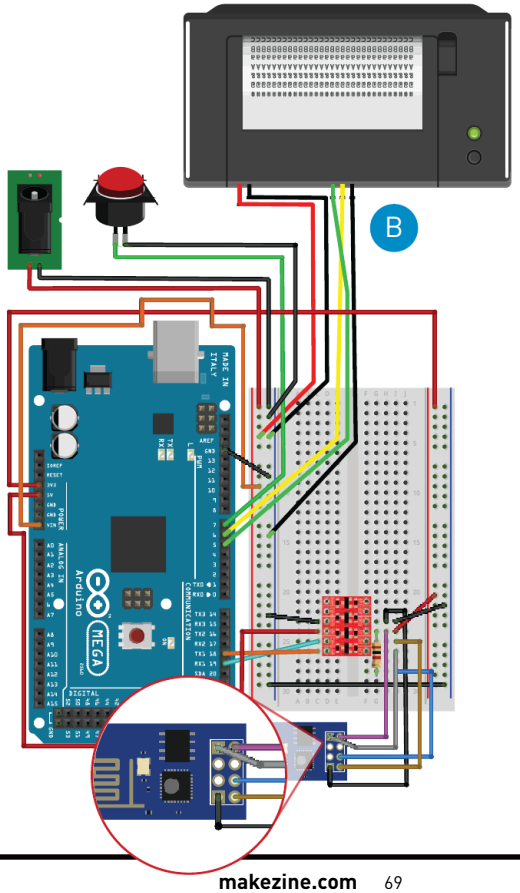
Materials

- **Arduino Mega**
- **Logic level converter** SparkFun #BOB-12009, sparkfun.com
- **Wi-Fi serial module ESP8266** Maker Shed #MKSEEED52 makershed.com
- **Thermal printer,** Adafruit #597, adafruit.com
- **Power supply, 9V 2A positive center**
- **Breadboard and jumper wires**
- **Mannequin head**
- **Female power jack, 5.5mm/2.1mm positive center**
- **Momentary pushbutton, round**
- **Resistor, 1k Ω**
- **Prototype shield (optional)**

Tools

- **USB cable for Arduino**
- **Dremel rotary tool**

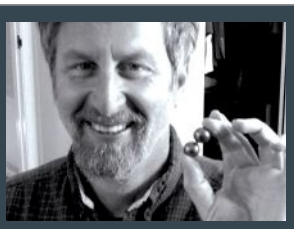




James Burke

Written by William Gurstelle ■ Illustration by Peter Strain

Giovanni Venturi and the VENTURI EFFECT



WILLIAM GURSTELLE is a contributing editor of *Make:* magazine. His latest book, *Defending Your Castle,* is available at all fine bookstores.

Time Required:
1-2 Hours

Cost:
$15–$25

Materials

- **Plastic or glass bottle or flask, vacuum-worthy, with airtight lid or stopper**
- **Flexible plastic tubing, ¼" ID, 18" length**
- **Hose fitting, double barb, ¼" diameter, plastic or brass**
- **Thread compound**
- **Venturi vacuum generator** aka venturi vacuum pump or air-operated vacuum pump. You could machine your own out of aluminum using Figure A as a guide, but mass-produced ones are inexpensive. I bought one from Harbor Freight Tools for $19, including the air hose and fittings I needed.

Tools

- **Air compressor and hose with ¼" female industrial-style coupler**
- **Adjustable wrench**
- **Screwdriver, slotted**
- **Safety glasses**

Rediscover the phenomenon that gave us carburetors, paint sprayers, scuba regulators, and your gas barbecue grill

GIOVANNI BATTISTA VENTURI WAS AN 18TH-CENTURY ITALIAN POLYMATH WHO DID A REMARKABLE NUMBER OF THINGS EXTRAORDINARILY WELL. He was an ordained Catholic priest, a university-level mathematics instructor, one of the leading civil engineers of his day, a politician and statesman (and a favorite of Napoleon Bonaparte), and a world-class historian. In fact, it was Venturi who first called attention to Leonardo da Vinci's scientific contributions.

Perhaps his greatest impact though, came from his trailblazing research in fluid mechanics. His discovery of the *Venturi effect* — the eponymous physics phenomenon he was first to describe — is the basis for various important contraptions today, from paint sprayers to fertilizer applicators to gas grills to scuba regulators.

In his 1797 book, Father Venturi describes how the motion of one fluid can "impress its motion on other fluids, by carrying them along in what I call the lateral communication of motion in fluids." Venturi discovered that air or water shooting through a constriction in a pipe can more or less magically drag fluid along with it from a second pipe, if the geometry of the pipes is just right.

Venturi really didn't understand the reasons

CAUTION: You'll need an air compressor in order to speed the air through the venturi, and high-pressure air must be handled with caution. Use your compressor in accordance with manufacturer's directions and wear protective eyewear.

When you draw a vacuum in a container, atmospheric pressure could cause it to implode. For plastic soda bottles, that's pretty cool. For other items, it's not so good. If you apply your pump to a glass flask or bottle, be sure it is strong enough to handle an atmospheric vacuum.

behind this phenomenon, now universally known as the Venturi effect. But it is easily explainable today using the important law of fluid mechanics known as the Bernoulli equation. Without getting into the math, we can state in broad terms that fluids under pressure and moving through a gradually narrowing pipe gain speed. That's easy enough to understand; since the number of fluid molecules going in and coming out of the pipe is constant, the fluid molecules have to speed up in order to move through the constriction.

Venturi's insight was that where the fluid speeds up, concurrently the fluid pressure drops. If you measure the pressure at various points in a system of pipes, you'll find it's lowest where the speed and pipe constriction are the greatest (Figure A).

That little nugget of knowledge is actually a huge scientific and technological bonanza. It turns out that a *venturi tube* (or just *venturi*) is a really neat way to move, push, drag, or mix one fluid by using nothing but the motion of another — Venturi's "lateral communication of motion."

Of the countless applications of what we now call the Venturi effect, probably the best known is the automobile carburetor. In a carburetor, air flows through a venturi channel, causing gasoline to be sucked in through a small opening in it, in just the right proportion. The combined fuel-air mixture goes into the engine's cylinders where the spark plugs ignite it and make the car go.

MAKING A VENTURI-STYLE VACUUM PUMP

Venturi's discovery can also be used to make a simple but effective vacuum pump. While there are many different types of vacuum pumps (see my column on Otto von Guericke and the Magdeburg Hemispheres in *Make:* Volume 31,) the Venturi-effect pump is certainly the simplest.

In this edition of Remaking History, you'll rig a venturi-based vacuum pump for less than $25. Vacuum pumps are pretty great science tools and lend themselves to a variety of interesting experiments.

1. Remove the vacuum module from the pump's plastic housing. Begin by using an adjustable wrench to remove the male air connector, then remove the tee fitting from the brass nipple (Figure B).

2. Use a screwdriver to open the plastic housing. Remove the housing and discard.

3. Reattach the tee fitting and industrial air connector onto the venturi module (Figure C). Use thread compound on the threads and torque it down to prevent any leaks.

4. Carefully work one end of the ¼" soft plastic tubing over the smaller of the screw thread fittings attached to the pipe nipple. Securely cap the larger fitting with the provided cap (Figure D).

5. Insert the hose barb into the other end of the soft tubing (Figure E).

6. To operate the pump, connect your air hose to the pump's air inlet (Figure F). Set the discharge pressure of your air compressor to between 70 and 90psi. The higher the pressure, the greater the vacuum your pump will draw. At 90psi, I obtained a vacuum of around 24" of mercury (inHg), equivalent to 11.79psi or 0.8 atmospheres. That's a lot.

FUN WITH A VACUUM PUMP

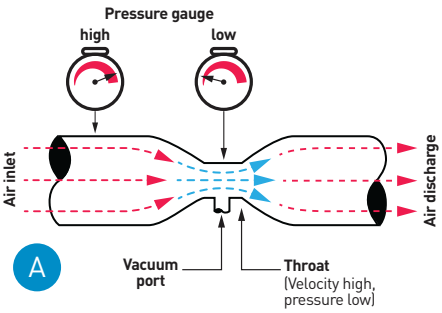
What will you do with your vacuum pump? Science! The easiest experiment is to drill a hole in the cap of a plastic soda bottle and insert the hose barb while the pump is running. It's oddly satisfying to implode bottles and then watch them regain their shape when the vacuum is removed.

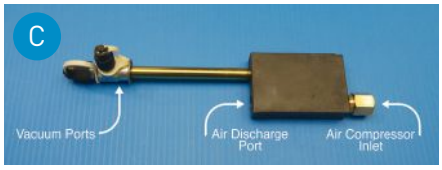
Another easy trick is to place a few marshmallows or a dollop of shaving cream inside a vacuum-capable flask or jar. Pull a vacuum and watch what happens to the stuff inside when it's liberated from atmospheric pressure (Figure G).

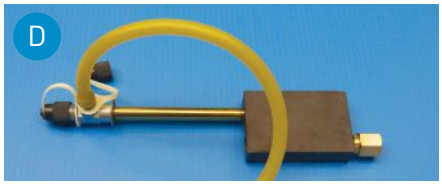
A classic experiment is to place a buzzer inside a container and then evacuate it. The buzzer will go silent or nearly so, since a vacuum can't propagate sound waves.

On a more practical level you can use your vacuum pump to service air conditioners, apply veneers to wood-working projects, or even vacuum-seal bags for sous-vide cooking. You'll find lots of interesting ways to explore Father Venturi's invention!

How would you use a venturi vacuum? Share at makezine.com/go/venturi-effect.







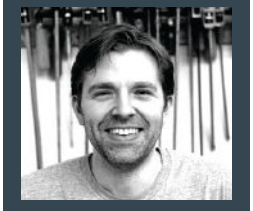
Anthony Lam, Hep Svadja

2×4 Project Enclosure

Create a one-of-a-kind case from scraps

Written by Ben Light

Time Required: 1-2 Hours
Cost: $0-$20



BEN LIGHT is a New York-based Maker, designer, and Cash Cab contestant. Ben's work has appeared in the Museum of Arts and Design, the MoMA Design Store, and on the shelves at Crate & Barrel.

Materials

- **Wood 2x4, 5-10" length, free of knots, holes, and defects.** Do not use pressure-treated lumber.
- **Drywall screws, 1" (4)**
- **Tung oil**
- **Furniture paste wax**
- **Rags**
- **Completed electronics project**

Tools

- **Drill press**
- **Hand drill**
- **Bandsaw**
- **Power saw**
- **Forstner drill bits, 1" dia. and 1.5" dia.**
- **Countersink bit**
- **Screwdriver**
- **Pencil**
- **Sandpaper, 180, 220, 400 grit**
- **Safety goggles**
- **Wood chisel (optional)**
- **Miter saw (optional)**
- **Power sander (optional)**

MOST SHOPS HAVE A BUNCH OF ELECTRONIC COMPONENTS ON THE WORKBENCH AND A LOT of scrap wood lying around — why not put them together? Here's how to create affordable, custom project enclosures out of common, inexpensive 2×4s. And they look pretty cool, too.

1. DRAFT LAYOUT

Select a completed electronics project that is ready to be enclosed, and a piece of scrap 2×4. Sketch out a rough layout of the circuit board and inner dimensions. Be sure to allow enough space to fit your project, and check that the depth of your components will fit inside the limited space of the 2×4. Make marks for screw placement.

2. CUT TO LENGTH

Using a handsaw or a power saw, cut the 2×4 to length — a little rough is OK, as some tear-out here and there adds character. I used a miter saw and cut to roughly 4.5".

Ben Light

3. DRILL AND COUNTERSINK SCREW HOLES

With a hand drill or a drill press equipped with a countersink bit, drill 4 screw holes in the corners of the piece of wood. Do not drill all of the way through the 2×4.

4. ADD THE SCREWS

Screw the four 1" drywall screws in place — there should be a bit of resistance when screwing them in for the first time — then remove the screws.

5. CUT OFF THE BACK

Using a bandsaw with the fence installed, cut about ⅜" off of the back (the side with the screw holes) of the 2×4. Don't worry if the cut is not that straight.

6. CORE OUT THE ENCLOSURE

From the rough sketch on the front of the block, mark the inner dimensions of the enclosure on the inside face. Set the depth of your drill press to avoid drilling all the way through, then use a 1" diameter forstner bit to drill the four corners of the space you mean to core out, leaving roughly ¼" of material at the bottom.

Secure the wood in a vice on the drill press and core out the remaining material using the 1.5" diameter forstner bit, again, leaving about ¼" of material at the bottom. If you need the extra space you can use a chisel to carve out the corners.

7. DRILL HOLES FOR COMPONENTS

Determine where you want to place your project's switches, dials, or other components and drill the proper-sized holes on the front of the enclosure.

8. SAND AND FINISH

Screw the enclosure together and sand it smooth by hand or with a power sander — I took mine to 400 grit.

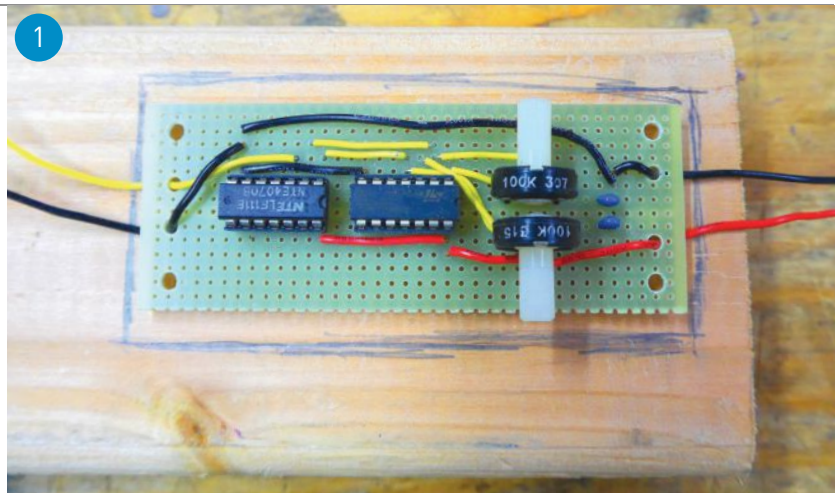
Paint or stain the enclosure, or apply tung oil and furniture paste wax to show off its "2×4-ness." Follow the manufacturer's application instructions.

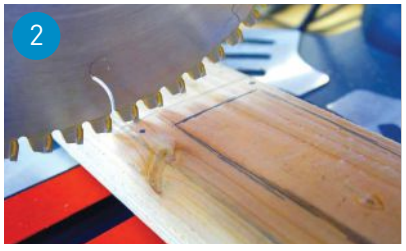
When everything is dry, attach all components and install any circuitry.

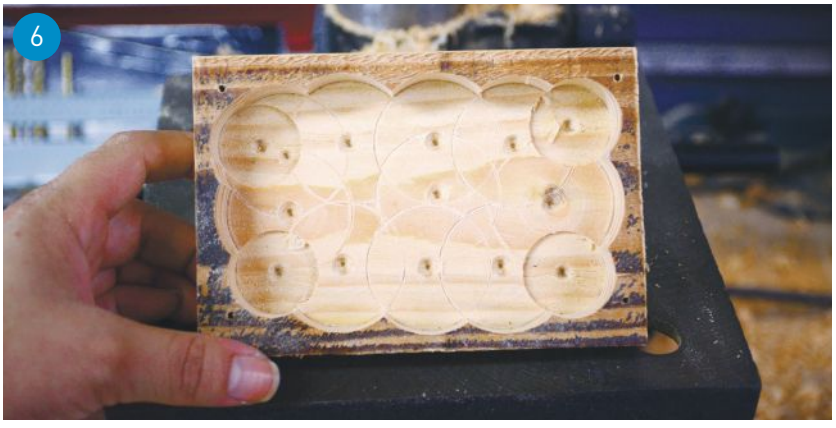
GOING FURTHER

When an enclosure is this inexpensive and easy to create, there's no reason not to experiment with its design. Try carving it into a unique shape before slicing off the back. Add handwritten labels to your switches and dials with a paint pen or woodburning tool. If you don't like the result, you can create a replacement in no time.

For a video on making your own wood enclosure, visit makezine.com/go/2x4enclosure.







Sandra Rodriguez

Make an Experimental Optical Fiber Seismometer

Written and photographed by Forrest M. Mims III

Detect quakes, landslides, and explosions with this sensitive DIY instrument

Time Required:
30–60 Minutes
Cost:
$35–$30

Materials

- **Laser pointer, cheap; or laser diode module** such as Digi-Key #VLM-650-03-LPA-ND, digikey.com. If you use the diode, add a simple SPST on-off switch.
- **Op-amp IC chip, TLC271 type** designated IC1 in schematic
- **LED, super bright, red**
- **Photodiode, BPW34 type** Jameco #1621132 or similar, or substitute a miniature solar cell; PD
- **Resistor, 3MΩ to 5MΩ** Higher values give more sensitivity; R1
- **Resistor, 10kΩ** R2
- **Solderless breadboard**
- **Plastic optical fiber, about 1m length** Jameco 2.2mm or similar
- **Fishing sinker, lead or steel** with central hole
- **Mini alligator clip leads (2)**
- **Battery case, 2xAAA**

Tools

- **Data logger (optional)**
- **Hot glue gun**

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.

VOLCANO ERUPTIONS, SLIPPAGE OF FAULTS, EXPLOSIONS, LANDSLIDES, DRILLING, AND EVEN TRAFFIC CAN CREATE VIBRATIONS in the Earth's crust known as seismic events or earthquakes. Seismometers are devices that detect seismic events, usually by mechanically or electronically detecting the movement of a suspended mass. Miniature accelerometers inside smartphones and video games also employ tiny movable masses to detect movements, and even seismic events.

OPTICAL FIBER SEISMOMETER

My son Eric Mims developed a novel seismometer in high school. His system was an optical fiber pendulum suspended from a steel frame bolted to the concrete slab under the carpet in his bedroom. A weight was attached to the free end of the fiber, which hung directly over an LED mounted under a pinhole. Seismic events caused the end of the fiber to oscillate back and forth across the pinhole. A photodetector at the opposite end of the fiber detected changes in light intensity, which were amplified and sent to a printer that Eric programmed as a chart recorder. This simple device detected earthquakes and two underground nuclear tests in Nevada, which earned Eric a record number of awards at the Alamo Regional Science and Engineering Fair in San Antonio.

BUILD AN EXPERIMENTAL OPTICAL FIBER SEISMOMETER

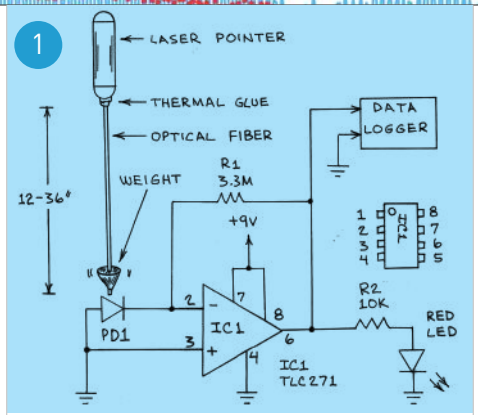
Figure 1 is an outline view and circuit diagram of a revised version of Eric's fiber optic seismometer, made with a fishing weight, a laser pointer or laser diode, and a photodiode or miniature solar cell connected to an amplifier. Insert the fiber into the open end of the laser pointer, and secure it with a hot glue gun. Insert the opposite end of the fiber through the central hole in a bullet-style fishing weight and glue it in place (Figure 2).

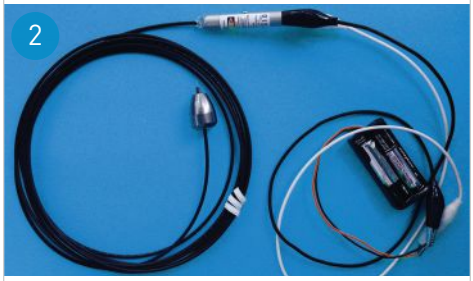
The detector circuit is built on a solderless board (Figure 3). The laser light emerging from the weighted end of the fiber is detected by the photodiode. The photocurrent from the photodiode is amplified by a TLC271 operational amplifier, the gain of which is determined by the resistance of R1. The higher the resistance, the more sensitive the circuit is to light. A red LED glows to indicate when the photodiode is receiving light.

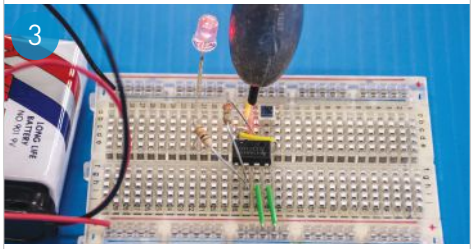
For initial tests, place the laser on a table and suspend the weighted end of the fiber over the table's edge. Place the detector circuit on the floor, and adjust the fiber until it's suspended just over the photodiode. Now darken the room completely, as external light will confuse the system. When the laser is switched on, the detector circuit's red LED should glow. Gently pushing or even blowing on the weight will cause the fiber to oscillate back and forth like a pendulum. Each time it sweeps over the photodiode, the LED will glow.

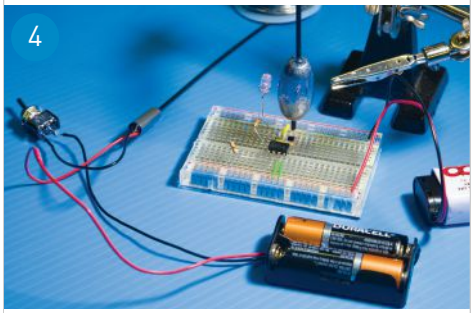
To detect very subtle movements, move the circuit board until the end of the fiber is over just the edge of the detector. Or make a pinhole in a square of black tape and place the tape over the photodiode.

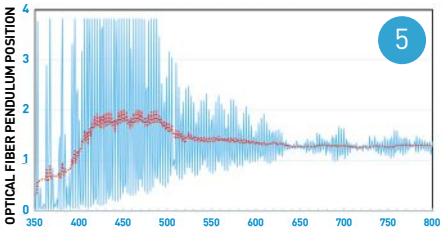
If you plan to detect earthquakes, install your seismometer inside a dark enclosure or closet, on the concrete slab or basement of a house. The LED can be connected to the circuit with wires long enough to allow it to be mounted outside the enclosure. The laser pointer will quickly exhaust its miniature batteries, so remove them and connect a 3-volt battery holder with a pair of AA or AAA cells to the pointer using tiny alligator clip leads. If your pointer has a pushbutton switch, close it with tape or a clothespin. Or you can substitute a laser











diode and on-off switch (Figure 4).

You can connect a data logger to the seismometer to provide a record of what it detects. Figure 5 shows a typical response of the seismometer when its weight is pushed slightly and allowed to swing until it is again stable. These data were logged by a 4-channel, 16-bit Onset Hobo UX120-006M Analog Data Logger.

MODIFYING THE SEISMOMETER

Connect a piezo buzzer or tone generator to the output of IC1 to provide an audible signal when movement is detected.

If you'd like to detect the in-line direction of the seismic event, replace the photodiode with a quadrant photodetector. Center the free end of the fiber at the junction of all four quadrants of the sensor. Connect each quadrant to its own op-amp and their outputs to a 4-input data logger like the Hobo. You can make your own quadrant detector from four miniature solar cells cemented to a base.

DAMPENING THE SEISMOMETER

While this seismometer is ultra-sensitive, it takes time to settle back to its neutral position after a seismic event. Dampening the pendulum reduces its sensitivity, while also reducing the time required to settle to neutral. Therefore, this improves the time resolution of the device.

The easiest way to dampen your seismometer is to simply shorten the fiber. Another way is to place a clear container with a flat bottom over the light sensor. Fill this container with clear vegetable oil and dip the weighted end of the fiber into the oil. The amount of damping is determined by the depth of the oil.

A VIDEO OPTICAL FIBER SEISMOMETER

The simplest way to determine the magnitude and direction of movement of an optical fiber pendulum during a seismic event is to place a video camera under the moving end of the fiber. The photo on the previous page is a 15-second time exposure of an oscillating optical fiber pendulum. A video was made of the moving end of the fiber with a Panasonic Lumix camera in video mode. The video was played on a Surface Pro 3 tablet, and a 15-second time exposure of the video was made with a Sony a6000 (ISO 100 at f7). When Eric saw this image, he suggested using a webcam that records video only when movement is detected. That's definitely on my list of things to do.

Share your seismometer (and data!) and learn more about DIY seismometry at makezine.com/go/optical-seismometer.

The Insomniac's Friend

Hack a night light with a new, dimmable red LED for better sleep

Written by Charles Platt and Jeremy Frank

Charles Platt

CHARLES PLATT is the author of *Make: Electronics*, an introductory guide for all ages, and its sequel *Make: More Electronics*. makershed.com/platt

Time Required:
2 Hours
Cost:
$5–$15

Materials

- **LED night light, white** such as Maxxima MLN-16, four for $10
- **Wire insulation** for the LED leads. Strip it from 18AWG wire, or use thin heat-shrink tubing.
- **LED, red, 20mA (maximum) at 2V forward voltage** Lite-On #LTL4HMEPADS or similar
- **Trimmer potentiometer, 5kΩ, with multi-turn screw** Bourns #3006P-1-502LF or similar
- **Heat-shrink tubing, large** or electrical tape

Tools

- **Soldering iron and solder**
- **Screwdriver, miniature**
- **Pliers**
- **Wire strippers and cutters**
- **Heat gun** or other heat source

IF YOU'RE AN INSOMNIAC, FALLING ASLEEP IS ONLY HALF THE BATTLE. STAYING ASLEEP CAN BE DIFFICULT, TOO.

Arizona sleep specialist Vincent X. Grbach believes that if you wake up in the middle of the night, any source of white light can cause the brain to think that a new day has begun. This means that if you look at a video screen during the small hours, or turn on the lights to go to the bathroom, you may find yourself feeling wide awake no matter how tired you really are.

Ideally, you need red lighting to keep you in a drowsy state.

This made us wonder if there's such a thing as a red night light. The answer is, yes and no. Some are available that cycle through a rainbow of colors, and can be stopped at one of your choice. But these tend to be quite bright, and even a red light shouldn't be brighter than necessary. We wanted one with adjustable intensity — and since we couldn't find it, we decided to build it ourselves.

• • •

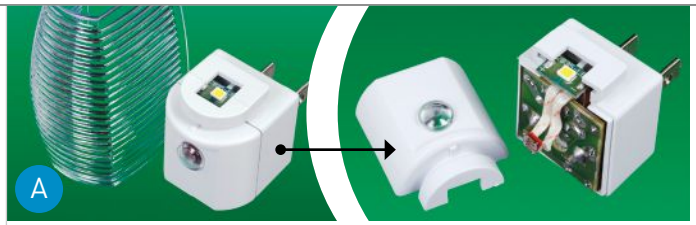
The easiest and most economical strategy was to adapt an off-the-shelf model. At Walmart, Target, and Lowe's, you can find white LED night lights that automatically switch themselves on when the surroundings are dim, and cost as little as $10 for a package of four.

Although these products look identical externally, some contain a surface-mount LED, while others use a through-hole LED with its leads enclosed in a plastic barrel. We'll show you how to modify either type.

First, an important warning: *Do not plug the light into the wall* when it is disassembled. No matter how careful you are, please don't test your modified light until you have put it back together.

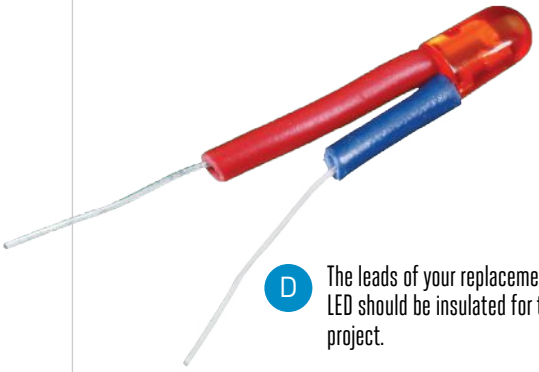
Figure A shows a light with its transparent cover detached, revealing a surface-mount LED (the little yellow square). Turn the body of the light around, and you'll find a screw between its two prongs. Remove the screw, and the front section of the body comes off.

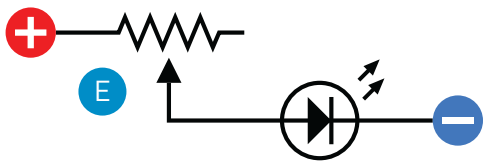
Polarity is shown with + and – symbols on either

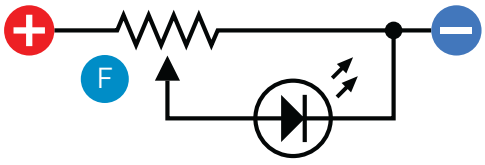

A white LED night light with its transparent lens and front body panel removed.


A night light using a white through-hole LED with its front removed.


The through-hole LED is detached by snipping its wires.


The leads of your replacement LED should be insulated for this project.


In this schematic, a trimmer functions as a series resistance.


Using the trimmer as a voltage divider allows a better range at the dim end of the scale.

side of the LED. Make a red mark on the body of the light to remind you which side is positive, then snip the wires to remove the little LED board.

What if you have the type of light that uses a through-hole LED? You can disassemble it in the same way, although you'll find that the LED is enclosed in a separate plastic barrel (Figure B). There are no + or – signs, but the LED has a flat spot on its round plastic body to identify the negative side. Make a mark to remind you of the polarity, then snip the wires, as shown in Figure C.

The next steps are the same for both types of night light. You'll need a generic red LED such as the Lite-On LTL4HMEPADS, which is typically happy with 2.1V forward voltage and 20mA forward current. Because white LEDs require a higher voltage, the night lights that we tested supply about 3.2V. However, we found that a red LED will pull the voltage down to almost exactly 2V while drawing 12mA, which is ideal.

Insulation is important, because a circuit failure inside the night light can result in house current getting to places where it shouldn't go. Protect the leads of the LED with heat-shrink tubing or with pieces of insulation stripped from 18-gauge wire (Figure D).

You have two options for circuits to dim the light. Figure E shows a potentiometer used as a series resistance, while in Figure F the potentiometer works as a voltage divider. Because the effective internal resistance of an LED varies with the current, a series resistance won't provide as much visual variation at the dim end of the scale. Therefore, we used the voltage-divider circuit.

Our trimmer potentiometer was a 5K Bourns 3006P-1-502LF. Attach the LED to it, as in Figure G. Curling the ends of the wires around the pins of the potentiometer with needlenose pliers will make them easier to solder in place.

Finally, enclose the trimmer pot and its exposed leads in large-diameter heat-shrink tubing (Figure H) or electrical tape, and then reassemble the light (Figure I).

After you put it back together and plug it in, cover the photoresistor with your finger, and a red glow should appear when you adjust the screw on the trimmer. Now you can brighten or dim the LED to your personal taste.

Those who are careful, patient, and have steady hands may be able to build a trimmer neatly into the plastic shell, and even add a little hole to allow external access to the trimmer's adjustment screw. Another option, if you want a softer, more restful glow, is to replace the ribbed lens of the night light with a section of transparent plastic tube, sanded on the inside to make it translucent.

Whichever way you package it, you'll be able to fine-tune your light so that its red glow is just bright enough for you to see your way around, keeping you in your desired drowsy state. And if your brain reacts at all to the soft radiance, maybe it will think of it as being sunset rather than sunrise.


The LED and trimmer soldered to the output from the board.


Heat-shrink tubing insulates the new LED assembly.


Done. Turn the trimmer's screw to dim!

See more photos and share your night light hacks at makezine.com/go/insomniacs-friend.

Written by Sean Michael Ragan

Battery Testing Tweezers

Sort your coin cells in a snap

Time Required: 2 Hours
Cost: $20–$30

Materials

- Soldering heat sink clips (2)
- Standoffs, 10mm insulated (2) with bundled screws
- Crimp-on ring tongue lugs, #8, 22–16 gauge (4)
- LEDs, 5mm red wide-angle (2)
- Heat-shrink tubing, 1/8" and 3/8"

Tools

- Hobby knife and scissors
- Hammer, pliers, and file
- Double-sided tape (optional)
- Ruler and marker
- Drill and bits: 1/8" and 13/64"
- Screwdriver, Phillips head, small
- Soldering equipment
- Lighter

SEAN MICHAEL RAGAN (smragan.com) is a writer, chemist, and longtime *Make:* contributor. His work has also appeared in *Popular Science*, *Chemical & Engineering News*, and *The Wall Street Journal*.

TESTING WATCH BATTERIES AND OTHER "COIN CELLS" IS TOUGH BECAUSE THEY'RE SMALL AND AWKWARD TO PINCH BETWEEN VOLTMETER PROBES. This insulated tool gives you a better way. All you have to do is squeeze: The cell's polarity is indicated by which LED lights up, the charge state by its brightness.

1. STRAIGHTEN THE HEAT SINKS

Unhook the jaws of one heat sink, then cut off and discard the rubber insulation. Straighten the bend with your hands, and then peen it flat over a hard surface with a hammer.

With pliers, grab one of the jaws where it thickens into the handle, and bend it back and forth until the metal breaks. Discard the fragment, then round the edge with a file. Repeat with the second heat sink.

2. DRILL THE HOLES

On each flattened heat sink, mark a centerline about 2" long, starting at the rounded end. Measuring from the same end, add tick marks at 3/16", 13/16", and 1 7/16".

Drill a 1/8" hole at each mark, then enlarge the center holes to 13/64" for the LEDs.

3. INSTALL THE FIRST LED

Assemble one jaw, 2 standoffs, 4 ring tongues, and 4 standoff screws as shown (Figure A). Insert one LED into the large hole from inside, then bend the long lead and insert it into the forward ring tongue on the same side of the standoffs as the LED and the jaw. Trim the lead as needed, and solder in place.

Slip a 3/8" length of 1/8" heat-shrink tubing over the remaining LED lead and apply heat to activate it. Bend this lead over and insert its bare end into the rear ring tongue on the opposite side of the standoffs. Trim and solder.

4. RINSE AND REPEAT

Mount the second jaw to the standoffs, then temporarily unmount the first jaw. Repeat Step 3 to install the second LED.

Reattach the first jaw, tighten the screws, then work a 1¾" length of 3/8" heat-shrink tubing over each jaw, from the front, and apply heat to shrink.

5. GO TEST BATTERIES

To use, squeeze a coin cell between the jaws of the tweezers. If neither LED comes on, the cell is dead. If an LED lights up, that is the cell's positive side. If it shines brightly, the cell is giving 3V or close to it (Figure B). If it shines softly, the cell is giving 1.5V. And if you need a more precise measurement, just add wire leads and banana plugs to connect the tweezers to your digital multimeter.

For complete step-by-step photos and tips, visit the project page at makezine.com/go/battery-testing-tweezers.

Hep Svadja (top); Sean Michael Ragan (A, B)

Written by Jason Poel Smith

Super-Size DIY Helping Hands

Repurpose a floor lamp to create a heavy-duty multi-arm tool

JASON POEL SMITH creates the "DIY Hacks and How Tos" video series on *Make:*. He has an undergraduate degree that is 50% mechanical engineering

Time Required:
1-2 Hours

Cost:
$60-$80

Materials

- **Floor lamp, poseable 5-light**
- **Spring clamps (5)**

Tools

- **Drill and bit set**
- **Pliers**
- **Tin snips**

HELPING HANDS ARE USEFUL TOOLS, BUT THEIR POTENTIAL APPLICATIONS are limited by their small size. So I decided to build a bigger and stronger version, allowing you to hold larger objects and affording greater range of motion.

1. GAIN ACCESS TO WIRES

With the lamp unplugged, open up the body and detach the lamp section from the stand.

2. DISCONNECT POWER CORDS

Unplug all the wires, separate them, and remove the power switch. Then pull the main power cord out through the bottom of the stand.

3. REMOVE LIGHT BULBS AND COVERS

Unscrew any light bulbs along with the plastic nut holding the lamp covers in place, allowing you to remove the covers.

4. DETACH LIGHT SOCKETS

If you are lucky, the light fixtures will simply unscrew. Unfortunately, some lamps do not give up their light sockets easily and require a more aggressive touch.

5. DRILL MOUNTING HOLES IN CLAMPS

Find a drill bit that is the same size as the mounting hardware on the lamp. In my case, the lamp had a standard lamp nipple and screw, so I used a ⅜" drill bit.

6. ATTACH CLAMPS TO LAMP ARMS

For simplicity, I reused the mounting hardware that attached the heads of the lamps.

7. REASSEMBLE STAND

Put the pieces of the switch housing back together, then secure them in place with the nut. Finally, screw the lamp arm assembly back onto the stand.

Now you have a heavy-duty helping hands tool. Use it to hold your tools, a flashlight, your instructions — even a cold drink.

For video and detailed steps, visit makezine.com/go/xl-help-hands.

Hep Svadja

Toy Inventor's Notebook

CUSTOM TIDDLYSHRINKS

Invented and drawn by Bob Knetzger

Time Required:
1–2 Hours
Cost:
$5–$10

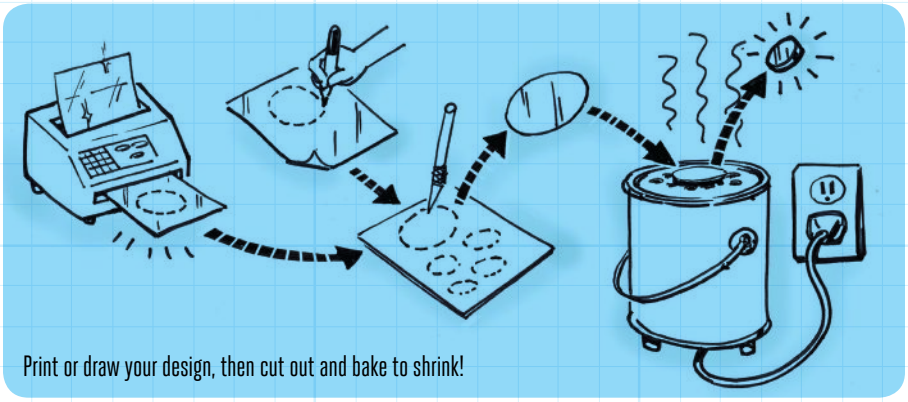
HERE'S A NEW TWIST ON AN OLD CLASSIC GAME THAT YOU CAN REMAKE ALL YOUR OWN. Tiddlywinks is played with a set of small, color-coded discs. Use your "squidger" (a large plastic disc or shape) to press down and scrape across the top surface of a "wink" (a small disc). When you snap its edge, the wink flips up into the air. With a little practice you can aim your wink to land inside the target cup.

Create your own custom squidgers and winks using shrink film — the kind that's sold under the Shrinky Dink name or generic brand at hobby stores. Draw and color your own design with permanent markers. It's easy to copy your favorite design: Place the clear film on top of the original and trace. Or create your design on the computer and use the special shrink film made for inkjet printing. Just remember, your design will shrink in size by about one-half!

Then cut the shapes out with a scissors or hobby knife. Shrink the plastic using your light bulb-powered EZ-Make Oven from *Make:* Volume 35 (makezine.com/projects/ez-make-oven). You can also bake it in your kitchen oven at 325°F or use a heat gun. As the thin polystyrene film shrinks, its thickness swells to 1/16". Heat it slowly and evenly to prevent curling.

When it cools, you'll have tough and strong plastic winks and squidgers of your own design in high detail!

Look online for many variations and strategies in tiddlywinks game play. Try for a "squop" (landing your wink on another player's wink, freezing it from play) but don't "scrunge" (bounce out of the target cup — oops!). The sky's the limit for your own custom tiddlywink graphics and themes: sports, movies, comic books — or mash them up. When you make your own you're not limited to the official licensed versions: *Star Wars* Angry Bird Basketball Tiddlywinks, anyone?



Print or draw your design, then cut out and bake to shrink!

Share your TiddlyShrinks designs on the project page at makezine.com/go/tiddlyshrinks.

MAGICFIRM ZYYX

A FEW SENSOR TWEAKS COULD TAKE THIS WELL-ROUNDED MACHINE TO THE NEXT LEVEL

WRITTEN BY MATT STULTZ

THIS SWEDISH REPLICATOR CLONE PRODUCES GREAT PRINTS IN MOST OF OUR TESTS and comes with some exciting new add-ons not found in other clones. With these upgrades, the ZYYX is attempting to push desktop 3D printing along — but is it too much too soon?

In addition to a fully enclosed build area, the ZYYX uses an exhaust fan with a carbon filter to reduce fumes. This is most useful when printing in ABS, but unfortunately, ABS also requires a heated bed to prevent curling, and the ZYYX lacks that.

SENSE-ATIVE

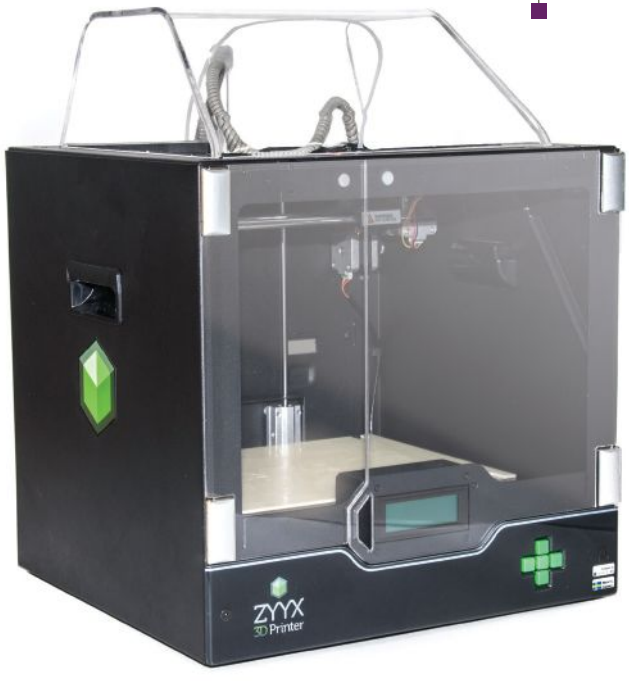
Bed leveling is a nonissue, with an integrated sensor and scripts. Three notches in the bed allow the print nozzle to descend past it, so that the button used to detect the print surface can come in contact with the bed without needing to move it during printing. This button has a secondary function as well: It detects if a print is too high and needs to be paused, avoiding print failure due to excessive curling. This is great in theory, but this implementation has problems. Prints with minor curling often set off the sensor, causing constant delays. After too many pauses, I disabled the sensor — thankfully just a matter of unplugging the cable to the switch — and this allowed for a successful print.

FILAMENT DETECTION

A filament sensor situated between the filament spool and the print head on the ZYYX detects jams and will also pause the printer. This is a great time- and material-saving feature; during my testing, a print paused due to a twisted filament spool. Turns out a narrow feed tube leading from the sensor to the print head was causing some excessive friction and a failure to extrude fully. Removing the tube completely fixed this issue.

CONCLUSION

Overall, the ZYYX is a well-rounded machine that, combined with its high-end slicer, Simplify3D, produces nice, large prints. Hopefully with a few tweaks, the team can get the issues around the extra sensors worked out and take this machine to the next level.



A filament sensor on the ZYYX detects jams and will also pause the printer

PRINT SCORES

	0	1	2	3	4	5
Vertical Surface Finish						
Horizontal Finish						
Dimensional Accuracy						
Overhangs						
Bridging						
Negative Space						
Retraction						
Support Material						
Z Wobble						

TOTAL 27

MANUFACTURER Magicfirm
PRICE AS TESTED $2,077
BUILD VOLUME 270×230×195mm
BED STYLE Unheated glass with custom plastic coating
FILAMENT SIZE 1.75mm
OPEN FILAMENT? Yes
TEMPERATURE CONTROL? Yes, tool head, 240°C max)
PRINT UNTETHERED? Yes (SD card)
ONBOARD CONTROLS? Yes (LCD with control buttons)
HOST/SLICER SOFTWARE Simplify3D
OS Linux, Mac, Windows
FIRMWARE Open, Sailfish
OPEN SOFTWARE? No
OPEN HARDWARE? No
MAXIMUM DECIBELS 51.2

zyyx3dprinter.com

PRO TIPS

If you experience repeated print pauses because the system improperly detects failing prints, you can unplug the sensor. Just make sure you plug it back in before starting the next print, or your head will crash when auto-leveling.

WHY TO BUY

The enclosed chamber and fume filtering are nice additions, and the extra sensors not only level the bed but can detect loose or over-curling prints and filament jams.

RESULTS

Matt Stultz is the 3D Printing and Digital Fabrication lead for *Make:*. He is also the founder and organizer of 3DPPVD and Ocean State Maker Mill, where he spends his time tinkering in Rhode Island.

Matt Stultz

TOOLBOX

GADGETS AND GEAR FOR MAKERS

Tell us about your faves: *editor@makezine.com*

Hep Svadja

WOODOWL OVERDRIVE LARGE BORE DRILL BITS

$75 (6pc set) woodowl.com

As soon as I pulled one of these WoodOwl wood drilling bits from its handy, rollable sleeve, I immediately found them appealing, thanks to one standout design feature: a quick-change ¼" hex shank that fits easily into a small drill chuck — even a ⅜" one. Lately I have been using a compact drill with a powerful battery that enables drilling and driving in limited workspaces, so I found the hex shank to be very useful.

The Japan-made set comes with 6 drill bit diameters, ranging from ½" through 1¼", but individual sizes and a 3-piece set are also available. I tested the bits in 1×4 scraps and they got the job done quickly and easily. Another nice feature was the brad point you could set into the center of your mark for enhanced precision, and chamfered edges for smoother starts.

I would recommend these bits especially for those who favor contemporary, compact, and ergonomic yet powerful drills. — *Marty Marfin*

KNOW YOUR BIG-HOLE BORING BITS

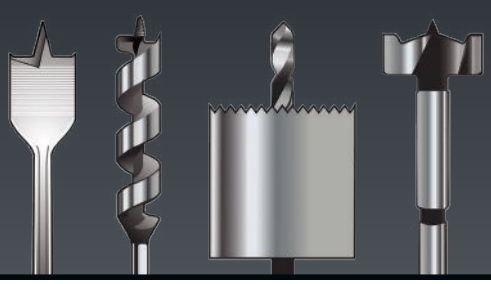
by Chris Weisbart

SPADE BITS: Spade bits cut fast and are self-centering. Not for metal — to be used with wood and plastics only. They dull easily, but are inexpensive.

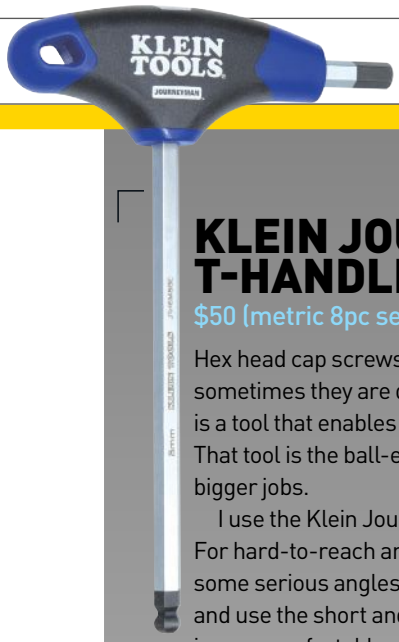
AUGER BITS: Used for making deeper, repeated holes. Fluting helps extract chips. They last longer than spade bits, but cost more, and have limited diameter ranges.

HOLE SAWS: Saw-toothed, cylindrical blades that attach to a drill-bit mandrel. Can be used on metal, but tend to bind (and twist your wrist) in deep cuts.

FORSTNER BITS: Unique because they cut a hole with a flat bottom. Great for mounting hardware that needs to be recessed in thicker stock. However, they are expensive.



James Burke



KLEIN JOURNEYMAN T-HANDLE BALL HEX DRIVERS

$50 (metric 8pc set); $65 (SAE 10pc set) kleintools.com

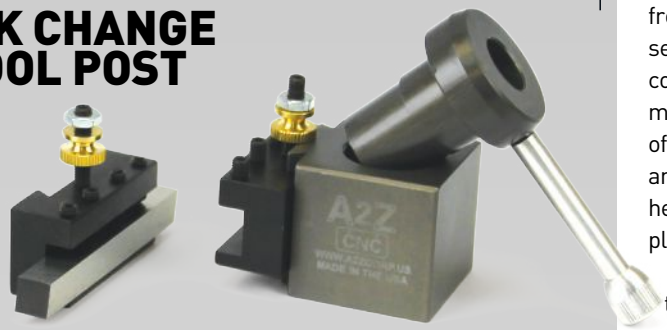
Hex head cap screws offer great gripping benefits and precision, but sometimes they are difficult to sneak into tight positions. Luckily, there is a tool that enables you to go in at an angle off-axis with the fastener. That tool is the ball-end hex key, but simple hex keys aren't always up to bigger jobs.

I use the Klein Journeyman Ball End T-Handles, and they're top notch. For hard-to-reach areas, the ball end can get in and turn a screw from some serious angles. When you need maximum torque you flip the handle and use the short and straight hex end with greater leverage. The handle is very comfortable and ergonomic — this is especially handy for small, precision work.

You can get the tools individually, or in sets that come with a quality metal stand that sits on your benchtop or mounts to the wall. They come in a variety of sizes in both metric and SAE (inch-based) styles. *— Dan Maxey*

A2Z QUICK CHANGE LATHE TOOL POST

$100 a2zcorp.us



One feature common to most home lathes is that they usually come with a rather basic cutting tool holder. It will hold the tool perfectly well, but will generally be a little inconvenient to use, requiring shims and other workarounds to get the tool centered. It usually isn't long before users start investigating the purchase of a quick change tool post (QCTP).

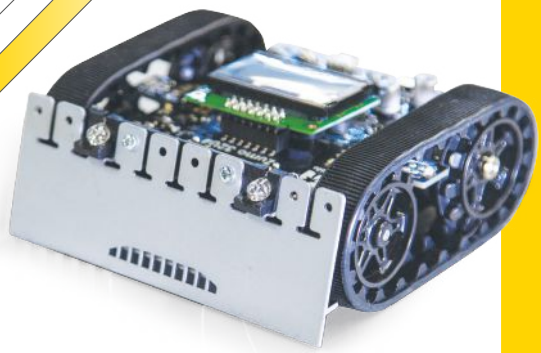
If your lathe is of the smaller, benchtop variety, like a Sherline or Taig, then you'll definitely want to consider the QCTP manufactured by A2Z. I purchased one for my Sherline three years ago, and I find it is perfectly suited to the precision metalwork I do at Clickspring. I don't have to waste time setting center height each time I change a tool, because each of my most commonly used cutting tools is already set up in its own tool holder, ready to go at any time.

The dovetail and piston design is sound, the construction is durable (anodized 6061 aluminum), and after several years of use, mine has a few battle scars but is still doing exactly what I need it to. The repeatability of the tool holder position is excellent considering how small it is, and the overall structure is sufficiently rigid to be a good match for the Sherline.

A2Z makes QCTPs for other sizes of lathes as well. Each set comes with the tool post, two standard tooling holders, a boring bar holder, and a cutoff blade holder.

If convenience matters to you in your shop, be sure to check it out.

— Chris B.



POLOLU ZUMO 32U4 ROBOT

$99 (kit); $150 (assembled with motors) pololu.com

Pololu's latest generation of programmable "sumo" style robot platform is not just meant for sumo robot competitions — the Zumo 32U4 is an enhanced and fully functional learning and experimentation platform.

To start, it is powered by an Arduino-compatible Atmega 32U4 microcontroller. Sensors, which aid in autonomous navigation, include IR proximity sensors at the front and sides of the robot, a line-following sensor array, and a 3-axis accelerometer, compass, and gyro. It's even got quadrature motor encoders. The user interface consists of three PCB-mounted buttons, plus reset and power on/off switches, a small but very helpful LCD display, and a buzzer that can play some music.

The Zumo 32U4 has a dual-motor, tracked drive system, which is both speedy and capable of handling small obstacles and reasonably steep inclines.

The real fun started when I explored some of Pololu's sample programs. My favorite was the self-balancing sketch. This particular example requires removing the front-mounted pushing blade (it's secured by 2 Phillips screws) and the line-following sensor board (tool-free removal and attachment). Watching the bot balance on its front wheels was extremely fun, but also really demonstrated the capability of the platform beyond just as a sumo robot. As someone who had never taken a deeper look at Pololu's previous Zumo bot, this was a real eye-opener.

Pololu offers the Zumo 32U4 as a kit, which requires soldering and your choice of micro gearmotor, as well as three pre-assembled robot options (with different motor speed and torque selection).

— Stuart Deutsch

LEATHERMAN TREAD

$165 leatherman.com

A lot of the reasons I love this product are the very reasons I wouldn't wear it: It's bulky. It's heavy. It's flashy man jewelry. You put it on and somehow feel both like a big, powerful lumberjack and dwarfed by its size. Is it a statement of your might, or a reminder of how lacking you are in big, tree-chopping, bear-wrestling forearms? Either way, it's a matter of style.

Because the Tread is not the most practical of tools. It has the go-everywhere element, provided you're willing to put up with it pinching your hair, bruising your wrist, and irritating your skin everywhere you go. (Actually, you get used to it pretty fast.) The tools are handy, if lacking a bit in leverage and difficult to get into small spaces. The sizing mechanism — i.e., removing links or half links — is rather imprecise. Unless you must have it for its novelty, stick with a pocket multitool.

— Nathan Hurst

ACTOBOTICS SCOUT ROVER CHASSIS

$170 servocity.com

This tough, low-riding chassis works as the starting point for a durable — not to mention cool looking — robot. The most obvious feature is the knobby 4.3" off-road tires. They're high-traction rubber covering cushiony foam, giving your project as smooth a ride as possible while gripping the terrain. Each wheel attaches to a 624rpm metal-geared planetary gearmotor, allowing impressive off-road capability.

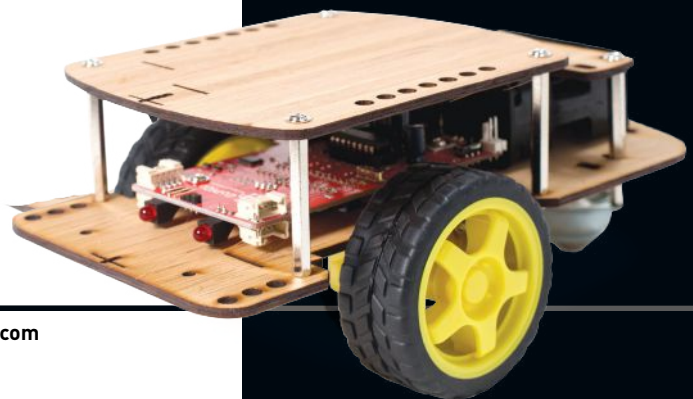
The 7.5"×10.5" top and bottom plates are ¼" ABS and feature the Actobotics hole pattern for the convenient mounting of hardware from that building set. The two plates are 1.32" apart, and all Actobotics hub mounts fit into this space, allowing you to easily change your robot around. In fact, with the exception of the ABS plates, all of the parts of this chassis are standard Actobotics products, allowing plentiful opportunities for remixing. *— John Baichtal*

DEXTER INDUSTRIES GOPIGO

$200 dexterindustries.com/gopigo

Teaching Raspberry Pi robots can intimidate, because not only do the teacher and student have to master the Pi, but there are all the robotics questions to answer as well, such as which motors and wheels to buy. The GoPiGo Starter Kit simplifies this by giving everything you need to create a basic rolling robot powered by a Pi. The kit comes with a Raspberry Pi B+, a laser-cut chassis, ultrasonic sensor, Wi-Fi dongle, motors and wheels, as well as a shield for a Pi that allows you to easily plug in the motors.

— JB



DEXTER INDUSTRIES BRICKPI

$170 dexterindustries.com/brickpi

The BrickPi allows you to control Lego Mindstorms motors and sensors using a Raspberry Pi computer as the brains, essentially taking the place of the set's controller brick. In addition to being able to control four Mindstorms motors and four sensors, the BrickPi breaks out the Pi's GPIO pins and can control non-Mindstorms electronic components like motors and sensors. Just being able to level-up Mindstorms' tepid wireless capabilities is a huge plus. The Starter Kit contains everything you need to get started, except the Lego parts. *— JB*

OPTICAL TELESCOPE ACCESSORIES FROM TELEVUE

Telescope eyepieces have improved a lot in recent years, from the optical clarity to the lens coatings to the field of view and eye relief. An eyepiece is judged by what it doesn't show you — blurs, reflections, and other artifacts. If you have astigmatism, you'll want to read about Tele Vue's astigmatism correctors (bottom), and then check with your eye doctor to find out which one to use.

— Michael A.Covington

DELITE TELESCOPE EYEPIECES

$250 televue.com

AVAILABLE FOCAL LENGTHS (MM): 7, 11, 18.2 (TESTED)
BARREL DIAMETER: 1¼" (31.7MM)
APPARENT FIELD: 62°
EYE RELIEF: 20MM

The view through Tele Vue's latest 18.2-mm DeLite-series eyepiece on my Celestron EdgeHD telescope is as free of eyepiece quirks as any I've seen. The stars are sharp over the central 90% of the field, and the image is bright and full of contrast. The eyepiece is solid, and the lenses have good anti-reflection coatings. Eye positioning is comfortable and not tricky.

Modern eyepieces have a wide field of view and generous eye relief, meaning you don't have to hold your eye uncomfortably close to a tiny hole. This series, dubbed DeLite to honor designer Paul Dellechiaie, is an excellent compromise between cost, bulk, and field of view. And they retain optical quality; more money and more bulk get you a wider field of view but not a sharper image.

A top-quality eyepiece won't cure optical limitations of the telescope itself. (For that, try Tele Vue's Paracorr lens, at least for fast Newtonians.) But if you want to be sure you're seeing what the telescope is showing you, DeLite eyepieces are an excellent choice. *— MC*

DIOPTRX ASTIGMATISM CORRECTORS

$105 (most strengths) televue.com

AVAILABLE STRENGTHS: 0.25D TO 3.50D (CYL.)

If you're nearsighted or farsighted, you can use a telescope without your glasses just by changing the focus. But if you have astigmatism, you have to keep your glasses on, which can be clumsy. Even with a top-quality eyepiece, I didn't realize how much it affected my view.

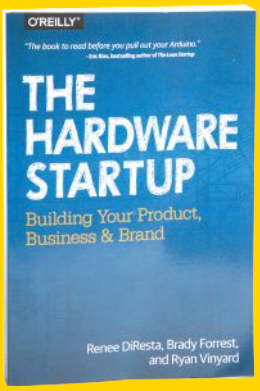
Tele Vue's DioptRx changes that. It fits on the flange that hold the rubber eyecup of most Tele Vue eyepieces. (Unfortunately, it's not designed to work with other brands.) Choose the DioptRx that matches the astigmatism part of your eyeglass prescription, put it on, and rotate it for the sharpest view — astigmatism is directional — touching up the focus as you go.

Your eye doctor may specify astigmatism as either positive or negative cylinder power. Tele Vue's lenses are negative, but they are equivalent to positive lenses if you rotate them 90° and refocus.

The result? The stars have an added crispness, and I no longer feel as much need to switch to higher power to resolve double stars or planetary detail.

One disappointment was that the lens axis is not marked. I found the right orientation of my DioptRx by going inside and reading fine print through it, then made a tiny "this side up" dot on the lens mount (not the lower ring marked A to F, which rotates freely until attached to the eyepiece). I also added a small piece of tape in the same position on the outer ring, so I can feel the orientation in the dark. *— MC*

BOOKS



THE HARDWARE STARTUP

by Renee DiResta, Brady Forrest, and Ryan Vinyard

$35 shop.oreilly.com

Renee DiResta, Brady Forrest, and Ryan Vinyard's *The Hardware Startup* offers 326 pages of insider insights, tips, and time-tested, experience-based processes for how to solve the common problems confronting hardware startups. This book is authoritative, accessible, and indispensable for anyone who wants to build a hardware company.

It covers the basics for beginners, such as widely used industry acronyms — DFM (design for manufacturing), DFA (design for assembly), RFQ (request for quote), PRD (product requirements document) — and supply chain management. But it also addresses less commonly discussed, though vital, topics such as the history of the Maker Movement and the legal considerations of designing a product. Because *The Hardware Startup* presents material in an exhaustive scope, even veterans of hardware companies will find this single volume useful and worth a look.

— David Scheltema

Skysphere:

The Shire's Newest High-Rise

WHEN JONO WILLIAMS ANNOUNCED THAT HE WOULD BE ASSEMBLING HIS NEW SKYSPHERE, there was much talk and excitement in the trendy Hobbiton. Standing at a towering 33 feet, this modern burrow kept all the comforts of a hobbit hole — not a nasty, dirty, wet hole, filled with the ends of worms, but a sky-hole, and that means comfort. The Skysphere is filled to the tip with a warm bed, hearty snacks, and an automated ale delivery system that hands the finest Barliman's directly to tired hobbit hands.

Near the end of the Third Age, common hobbit quarters began to shift to above-ground brick abodes, supplanting the traditional diggings. Bag End itself stands as a museum to history and ancient artifacts of gold and Mithril. As the hobbits leave the Sixth Age, technology, co-ops, and fine craft brews dominate the landscape. Despite these advances the hobbits have never seen or sailed the seas, or travelled much, at least not to whatever they can already see on Instagram.

To build his new home, Jono went to the Men of Gondor to authorize a loan, and for a mere $50,000 he began his journey. He ordered the steel hastily, before he ever took up the great wizard art of welding, and long after he determined to make the Skysphere himself. In just over two years and eleventy days, Jono had mastered skills to finish his abode.

With it completed, Jono sat at the window, looking out west onto a garden. The late afternoon was bright and peaceful. The flowers glowed red and golden. Sensing the beginning of day's end, Jono turned to his phone and adjusted the mood-lighting LEDs to match the flowers' petals. He browsed his horror film collection for an Orcish flick. While the world is indeed in peril and in it there are many dark places, for hobbits there's still Hulu and Netflix.

Ultimately, some things that should not have been forgotten were lost. History became legend. Legend became BuzzFeed filler. And for five and a half thousand years the ring was forgotten in a dusty room at Bag End, passed over by all knowledge online. Until, when chance came, the ring ensnared a new bearer, who foolishly ignored a "Do Not Touch" sign so he could take an edgy selfie for his dating profile.

Jono Williams

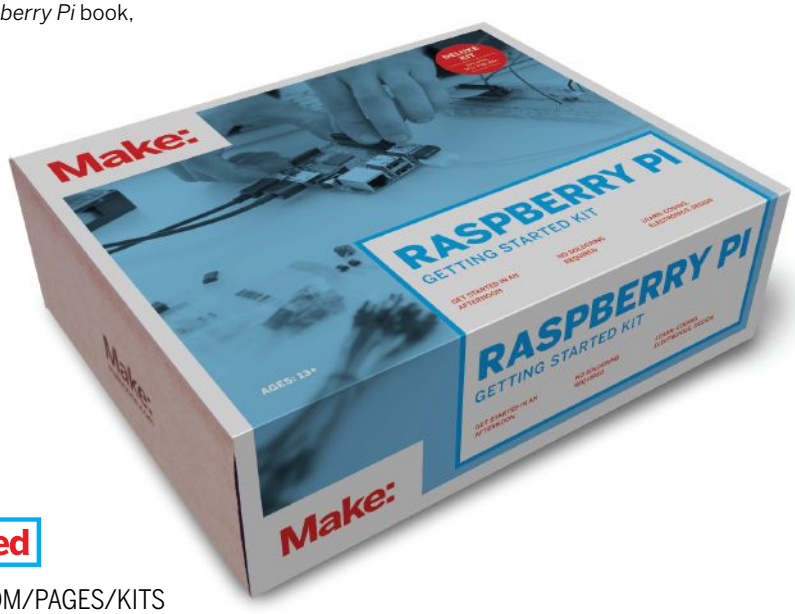
Make:

GETTING STARTED KIT

Raspberry Pi, Special Edition

NOW IS THE TIME TO GET STARTED WITH RASPBERRY PI

Raspberry Pi is a low-cost, Linux-based computer that's the size of a credit card. Our deluxe kit contains the Raspberry Pi 2 board and case, our own Make: *Getting Started with Raspberry Pi* book, 8GB Micro SDHC card, Wi-Fi adapter, and 60+ circuit components so you can begin your coding and electronics projects right out of the box.



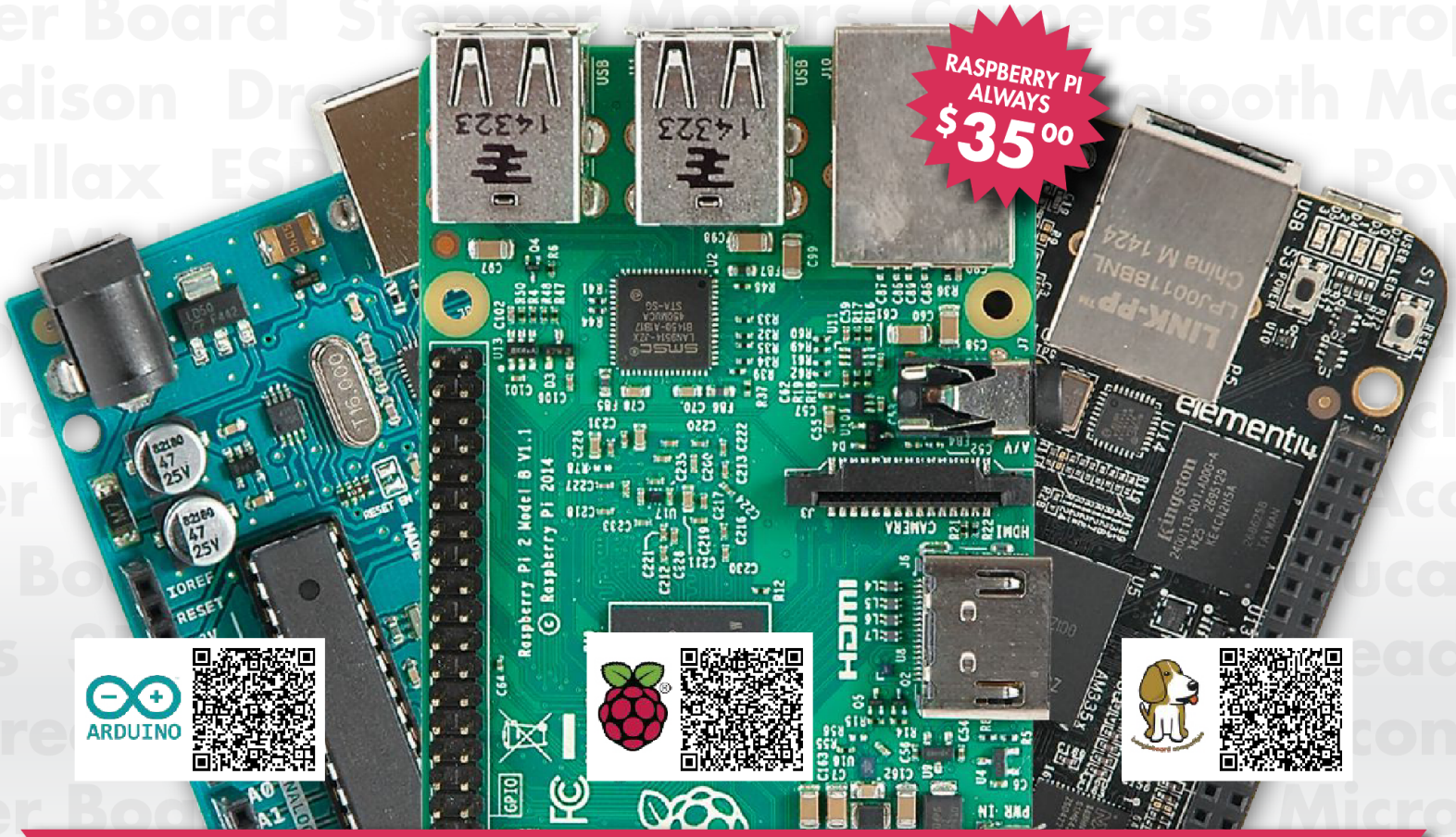
Maker Shed

MAKERSHED.COM/PAGES/KITS

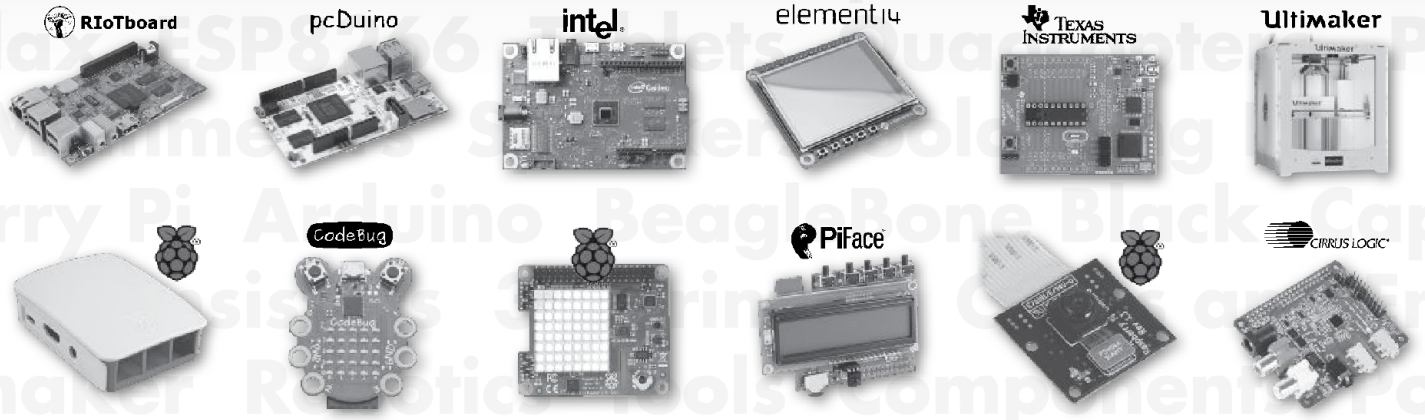
MCM

Your Maker & DIY Specialist

MCM Electronics is a Master Distributor for Raspberry Pi, BeagleBone Black, & Accessories



From Arduino to Zener Diodes, MCM Electronics has thousands of products for every maker!



MCMelectronics.com/Maker