SPECIAL ISSUE: 3D PRINTER BUYER'S GUIDE ▸23 PRINTER REVIEWS!

Make:

3D SCANNERS ▸ ARE HERE
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NEW FOR 2014

ULTIMATE GUIDE TO 3D PRINTING

$300 TO $3000: WHICH PRINTER IS RIGHT FOR YOU?

Printer + CNC all-in-one
Here comes the "everything" machines

MakerBot and Stratasys
What a $617M acquisition means for 3D printing

3D Printing Photo Booth
Turn your guests into figurines

DIY Filament Extruder
Say goodbye to expensive plastic

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Build an easy LED circuit that senses "hot and cold" distances.

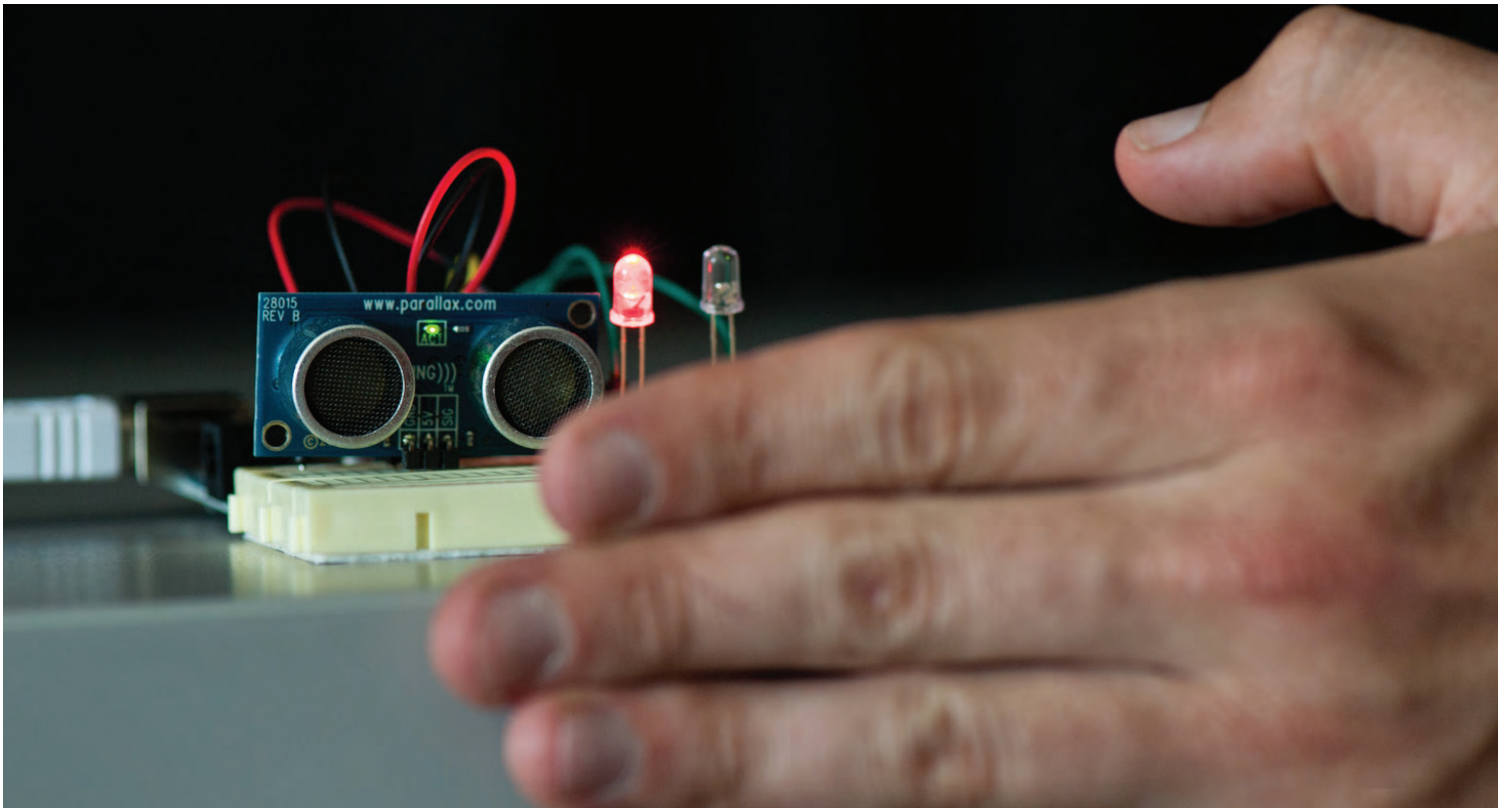
In this project, you'll combine an Arduino microcontroller, a Ping ultrasonic sensor, and LEDs to build a circuit that senses distances as "hot" and "cold." Then you'll run 3 Arduino programs (called "sketches") that use this "hot/cold" information in very different ways. It's an easy project that requires no soldering, so it's perfect for beginners. And it's a great way to learn how a single circuit in hardware can be made to perform all kinds of tricks in the software that runs on the microcontroller.

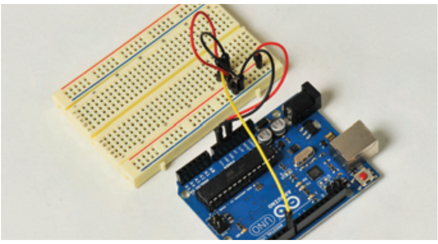
Sketch 1 measures distance from the sensor. When you're far away, the "cold" blue LED glows. As you move closer, the "cold" LED fades and the "hot" red LED turns up to full brightness!

Sketch 2 is a "capture the Ping" game. The "cold" blue LED glows, and every so often, the "hot" red LED flashes. When the red LED is on, quickly move your hand in front of the sensor. If you're fast enough, the red LED will flash. Got it! If you're too slow, the blue one will flash. Fail!

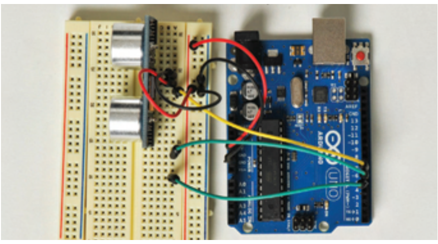
Sketch 3 is a simple "hot/cold" switch. The "cold" blue LED pulses slowly until the sensor detects an object — then the blue LED turns off and the "hot" red one shines at full brightness. Use this switch to trigger effects — such as alerting you when someone arrives, or waking your computer when you sit in front of it.

—Keith Hammond, MAKE Projects Editor

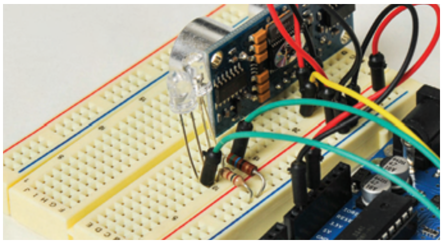




1. Jumper the Arduino to the bread-board.



2. Connect the Ping ultrasonic sensor to power, ground, signal.



3. Add the super-bright LEDs and their resistors.

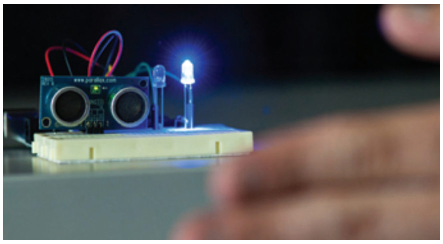
```
void loop() {

 // measure distance: send "Ping"
pinMode(SensorPin, OUTPUT);
digitalWrite(SensorPin, HIGH);
delayMicroseconds(5);
digitalWrite(SensorPin, LOW);

 // measure distance: listen for "Ping"
pinMode(SensorPin, INPUT);
pulseDuration=pulseIn(SensorPin, HIGH);

// divide by two (back/forth for a single trip), divided by speed of sou
pulseDuration=pulseDuration/2;
distance = int(pulseDuration/29);
```

4. Upload the Arduino program to the microcontroller.



5. The LEDs glow to tell distance: blue = far (cold), red = near (hot)!

```
// divide by two (back/forth for a single trip), divided by speed of sound = di
pulseDuration=pulseDuration/2;
distance = int(pulseDuration/29);

// light up red led: inverted linear of 0-25cm to 0-255 eq. off to max. brightn
if (distance > 0 && distance < 25) {
  int RedValue=(25-distance)*10.2;
  analogWrite(RedLedPin, RedValue);
} else {
  analogWrite(RedLedPin, 0);
}

// light up blue led: 10-90cm ^= 0-255, 25-50cm ^= 255-0 on BlueLedPin
if (distance > 10 && distance <= 90) {
 int BlueValue = (distance-10)*17;
 analogWrite(BlueLedPin, BlueValue);
```

6. Experiment with more "hot/cold" Arduino programs.

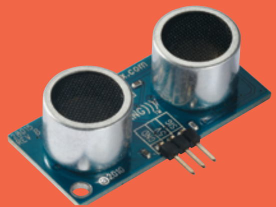
Learn to use an Arduino to read a distance sensor and control super-bright LED lights, without any soldering!

Parts list:

- USB cable, A to B
- Super-bright Blue LED, 5mm, 30mA @3.5V
- Super-bright Red LED, 5mm, 25mA @1.86V
- Resistor, 56Ω, 1/4W, for Blue LED
- Resistor, 150Ω, 1/4W, for Red LED

Arduino Uno microcontroller

Carbon-film resistor



Ping ultrasonic distance sensor

- Breadboard Jumper Wires

Tools checklist:

- Computer running Arduino software (free download from arduino.cc)
- USB cable, A to B (not pictured)

For complete instructions and details on this project visit:

radioshackdiy.com/hot-cold-LEDs

radioshack™

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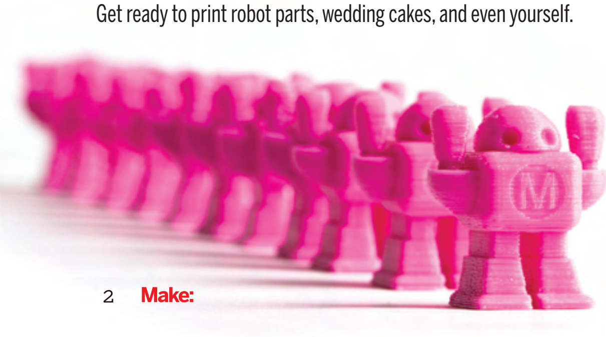
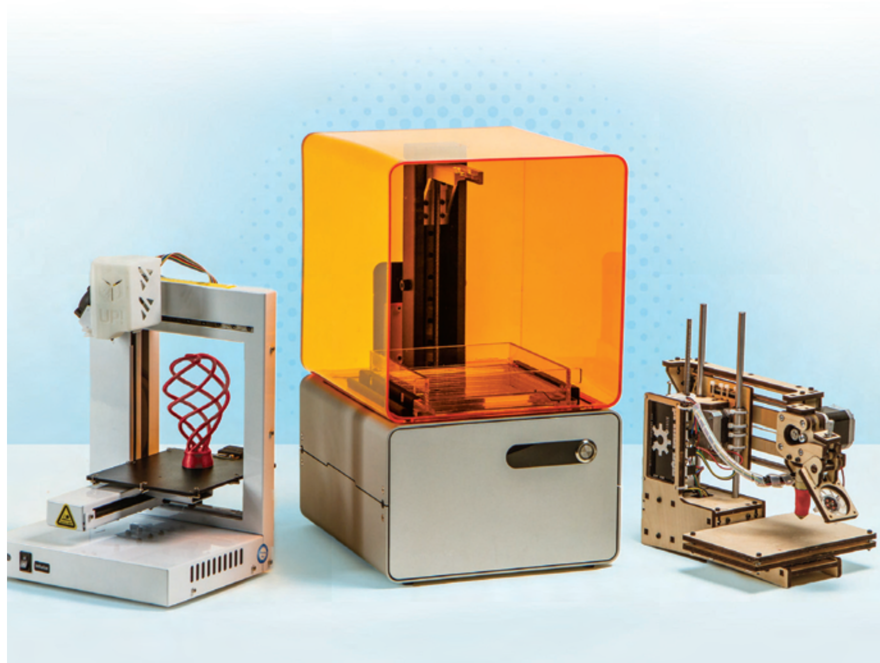
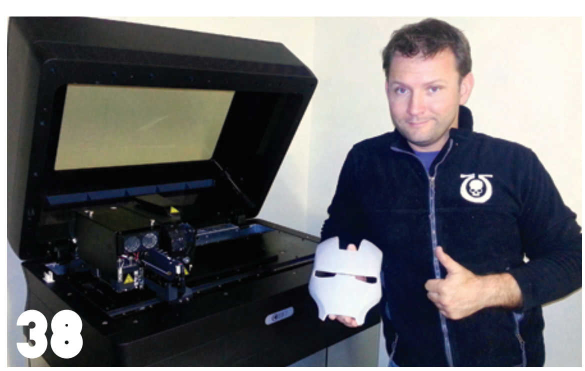




ON THE COVER
Up Plus 2, Form 1, and Printrbot Simple highlight our 3D printer roundup. Spiral Lightbulb Sculpture by benglish.



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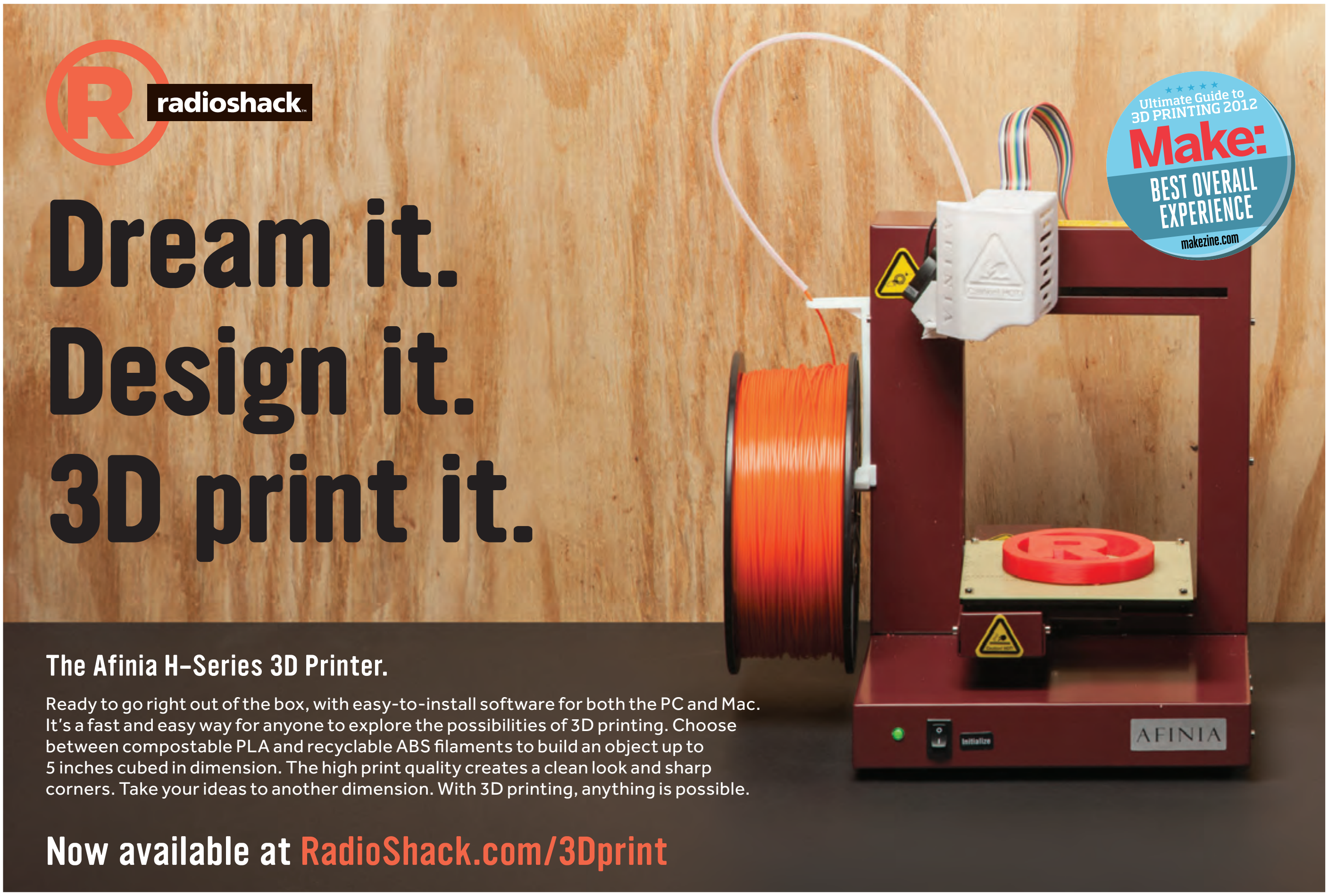
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"If you always want what you can't have, what do you want when you can have anything?"
—Tagline from Primer, 2004

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MAKE SPECIAL ISSUE: Ultimate Guide to 3D Printing 2014 is a supplement to MAKE magazine. MAKE (ISSN 1556-2336) is published bi-monthly by Maker Media, Inc. in the months of February, April, June, August, October, and December. Maker Media is located at 1005 Gravenstein Hwy. North, Sebastopol, CA 95472, (707) 827-7000. 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 Sebastopol, 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

A BRIEF HISTORY OF PERSONAL 3D PRINTING

WRITTEN BY **DALE DOUGHERTY**

Gregory Hayes

The first patent for 3D printing was obtained by Charles Hull in 1986, the same year that laser printers were patented and became available. Hull went on to found 3D Systems, which became one of the leading companies in industrial 3D printing. The essence of 3D printing is that software can "slice" a 3D image into a stack of 2D layers, and a machine builds the object by printing one layer on another. Sometimes called "additive manufacturing," 3D printing sounds like magic. It can be mesmerizing to watch a printer (by most definitions, a kind of robot), but it's also tediously slow, taking anywhere from 20 minutes to 20 hours to build objects that will fit in the palm of your hand.

After nearly two decades of industrial use, the personal 3D printing revolution started in 2005 with an open source project known as RepRap. Its overriding goal was to create a machine that could replicate itself. Its small but avid community of developers came up with a series of "evolution-themed" machine designs (Darwin, Mendel), while others created a software toolchain that could take .stl (for stereolithography, a term coined by Hull) files that describe a 3D model and generate the so-called "g-code" instructions that tell the machine what to do. The RepRap project, however, initially seemed to have trouble producing a machine that humans could build, let alone a self-replicating machine. (A maker who recently built a current RepRap model was able to print about 40% of the parts for his machine on another 3D printer.)

Frustrated by the process of building a 3D printer and realizing others were having the same problems, Bre Pettis, Zack "Hoeken" Smith, and Adam Mayer founded MakerBot in 2009. They sought to provide a kit version based on the RepRap designs but with enough improvements that they were easier to build.

The difference between RepRap and MakerBot was somewhat between baking from scratch and buying a box with all the measured ingredients you need to make something — and the first product from MakerBot was called the Cupcake. This kit took hours to assemble, and even then it wasn't perfect, but it was better than other options available at the time. The buyer of a Cupcake still needed special skills and patience to make it work properly. Other makers of 3D printers took the Cupcake as inspiration that they, too, could build a better printer.

In 2012, several changes began happening. MakerBot began working on a new version of a printer that would come fully assembled. And they began getting competitors from above and below. From above, manufacturers of industrial printers started producing their own personal printers, such as the Cube from 3D Systems. From below, others who were inspired by MakerBot's success began creating their own models, often using Kickstarter to raise money for development and production. Some of them were uninteresting, "me-too" rip-offs promising the same features and functions at a lower price. Yet more of the entrants offered solid competition, such as Ultimaker, MakerGear, Printrbot and Afinia. Still, even though there were more models and more manufacturers, demand exceeded supply.

In last year's *Ultimate Guide to 3D Printing*, we reviewed 16 different models of personal printers. This year, we tested 22 models, all of them coming to us assembled rather than as kits. Many of the personal printers do a good job at printing objects. While there is some differentiation in design and performance among the models, the biggest factors for usability are the software and documentation, which still favor the enthusiast willing to spend lots of time figuring things out. Buyer beware: The out-of-box experience is not at all like that of ordinary printers. The best way to have success in printing is to ask others in the community for help. The maker community has been key to the growth of 3D printing, providing not only tech support but also improving software and hardware.

With a price averaging around $2,000 and with capabilities that come close to their upscale competition, personal printers are in the hands of makers who are exploring the potential to turn rough ideas into real objects. Are you ready to join the 3D printing revolution? When you do, what will you make?

Dale Dougherty is founder and CEO of Maker Media.

WHOSE PROBLEM IS IT?

If you make a tool and sell it to someone who goes on to break the law, should you be held responsible?

WRITTEN BY **CORY DOCTOROW**

Let's start by getting the question right. The wrong question is, "Will 3D printers be used to infringe copyright, trademark, and patents?" The answer to that is an emphatic and unequivocal yes. The right question is "Whose problem will this be?"

Whether you're making printers; distributing plans for printers; hosting a site for model files; printing things that people bring you; or even processing payments° for 3D prints, printers, or feedstock, you are a potential target for people who are upset about their copyrights, patents, and trademarks.

In 1976, Sony got sued for unleashing the first VCR upon the world. They'd advertised it as a way of recording feature-length movies from TV to tape for watching and taking over to friends' houses. The big movie studios, led by Universal, spent the next eight years fighting Sony over the device's existence. Now the studios didn't say that the VCR actually infringed on their copyright. A VCR is not a copy of a movie. Instead, they said that *some of the things that people could do with VCRs infringed their copyright*, and for that reason the VCR should be banned.

The courts went back and forth on this for years. If you make a tool and sell it to someone who goes on to break the law, should you be held responsible? It's not a standard to which we hold toolmakers usually, and that's a good thing, because cars, hammers, kitchen knives, and computers are all routinely used to break the law, and no one would be able to afford to make or sell them if they had to be responsible for what their customers did with them. In 1984, the Supreme Court narrowly ruled in Sony's favor and laid down the "Betamax rule": If a device is capable of sustaining a substantial noninfringing use, then it is lawful to make and sell that device. That is, if the device is merely capable of doing something legit, it's legal to make, no matter how it's used in practice.

But by the mid-2000s, the Betamax ruling was in tatters. A case against Napster took a huge bite out of Betamax. The judge established the principle that if you had knowledge of someone misusing your product and the ability to stop it, you are legally obliged to take action. This standard flies in the face of existing practices. It