PROJECTS ■ THEORY ■ APPLICATIONS ■ CIRCUITS ■ TECHNOLOGY

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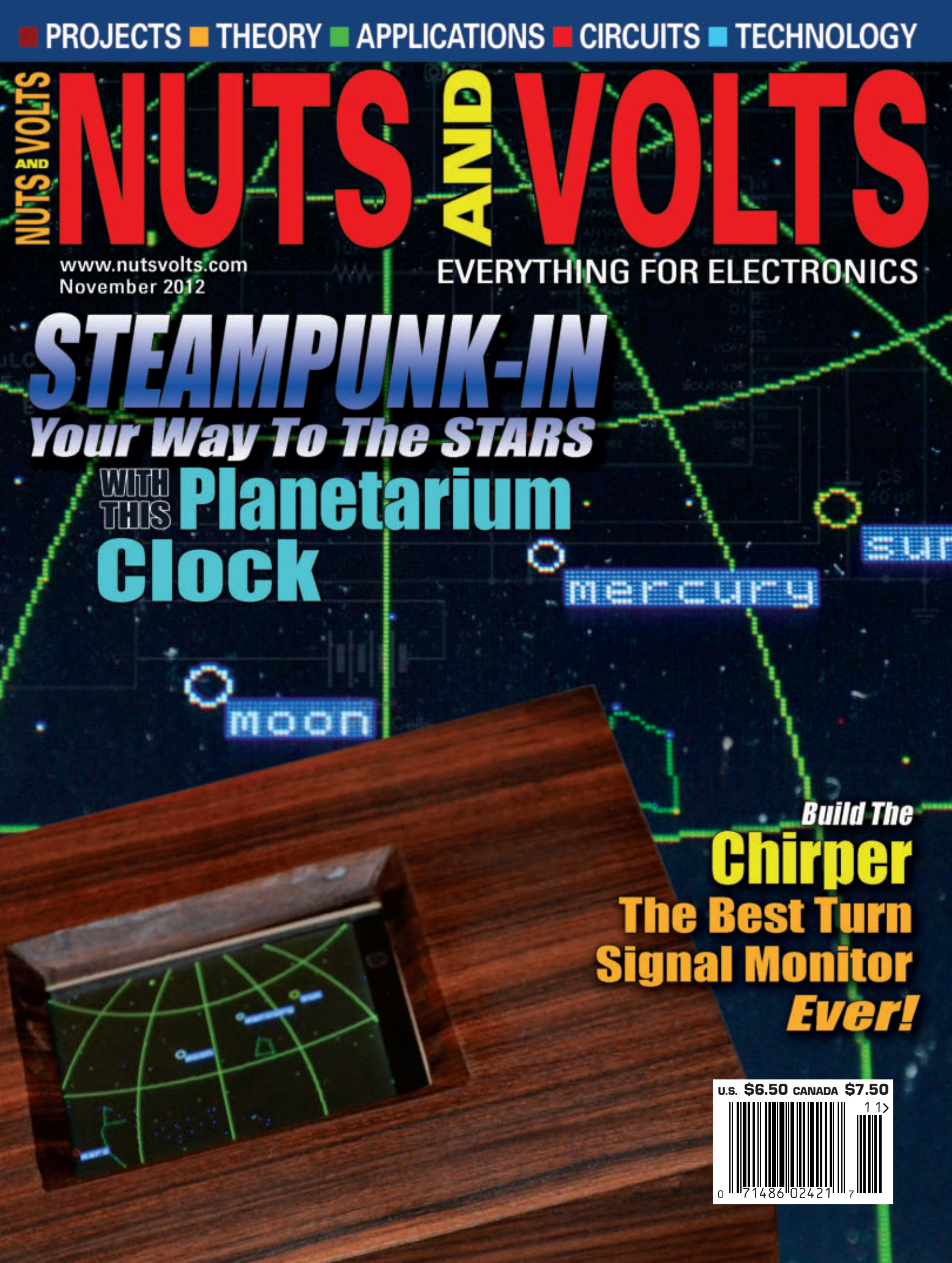

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Eight UARTs	Eight UARTs
Five I2C	**Four I2C**
Two CAN	Two CAN
3 SPI	3 SPI
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SSI	SSI
MicroSD flash card	MicroSD flash card ready
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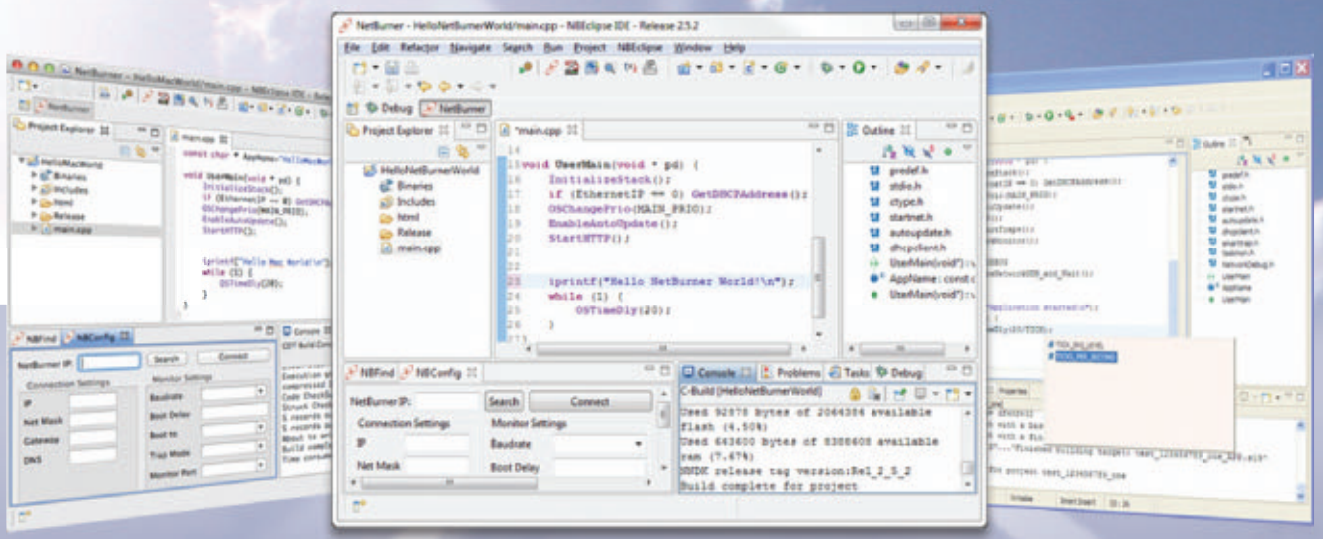
Two digital to analog converters (DAC)	Two digital to analog converters (DAC)



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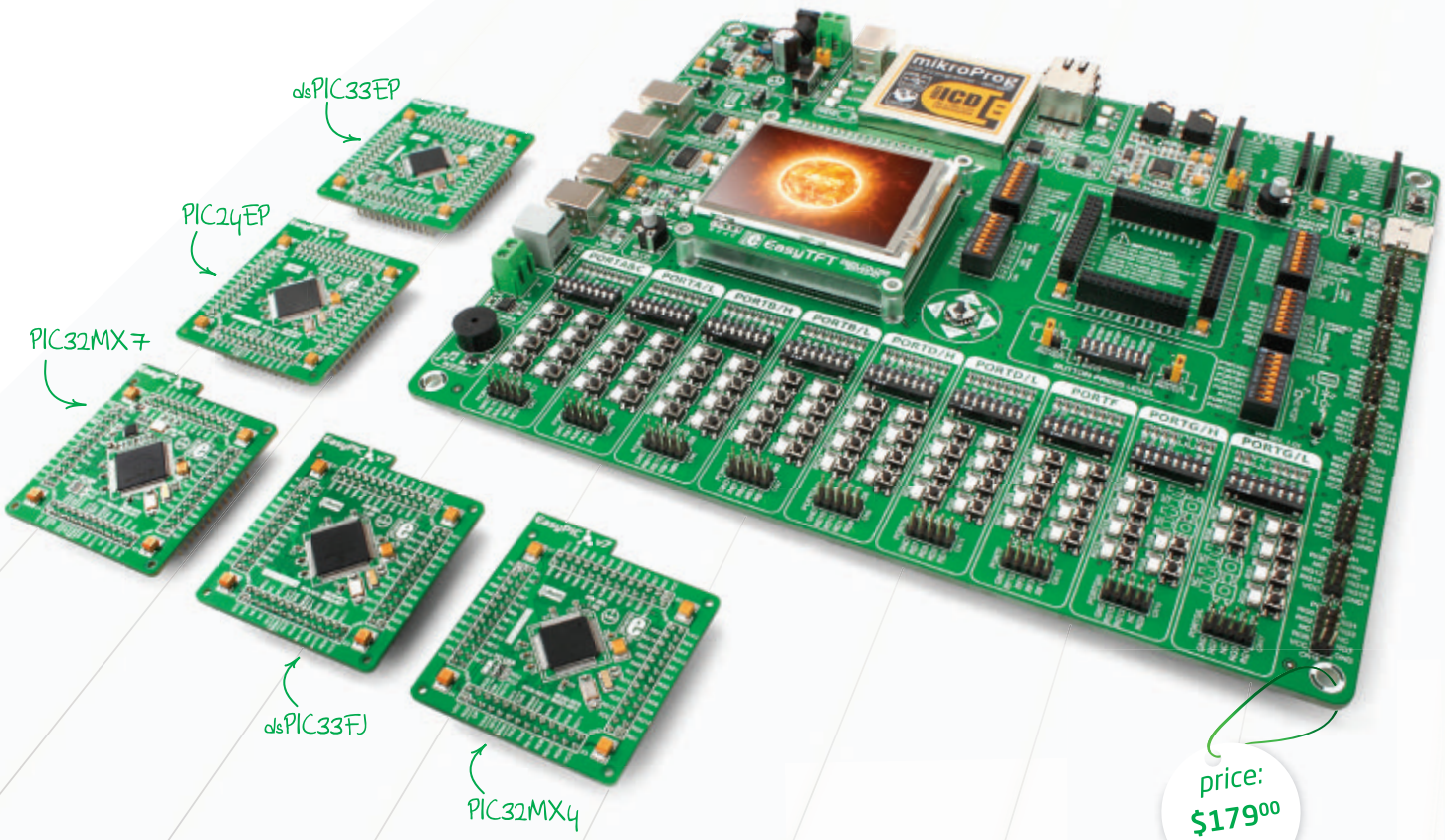

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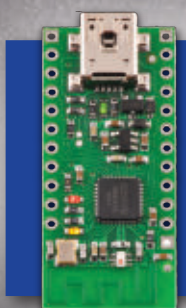
do more wire less

Wixel



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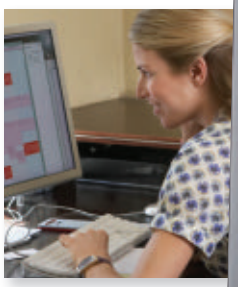

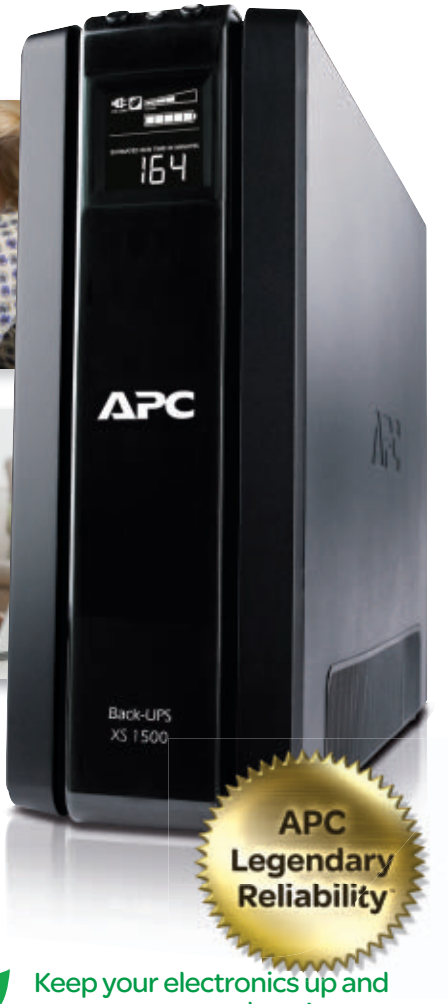

even when the power goes off.

Preserve what's most important to you.

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Whether DVRing your favorite show, updating your Facebook status, or playing a live networked game, you depend on your home electronics every day, all day. That's why APC™ by Schneider Electric™ has designed battery backup solutions that protect the constant availability and connectivity you expect … and depend on.

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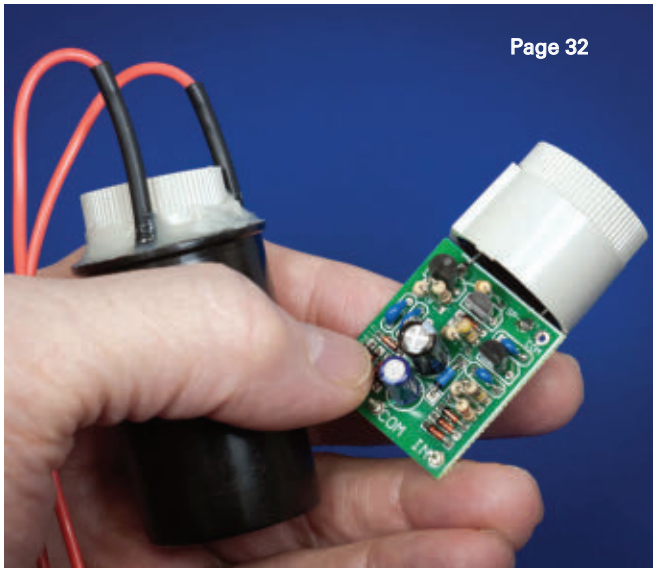

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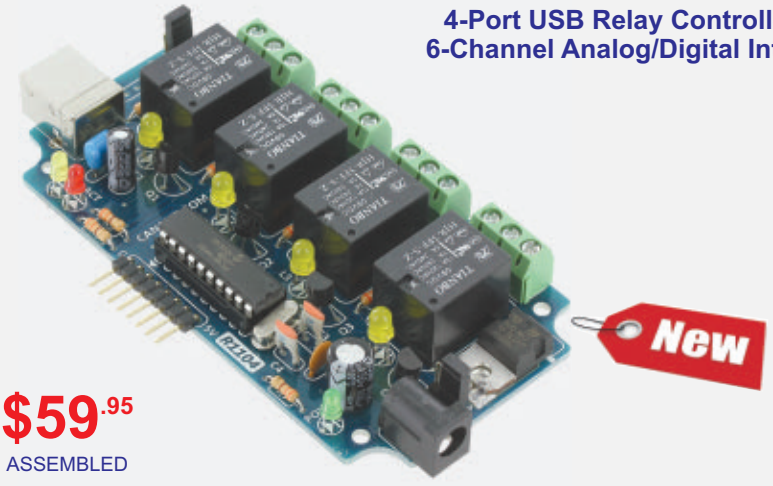

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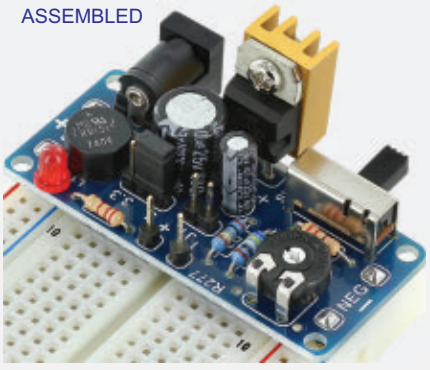

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DEVELOPING PERSPECTIVES

Hand-Wired Electronics

One reason I follow the music electronics industry is that it's usually on the leading edge. There seems to be a constant stream of embedded systems for adding sound effects to percussion, string, and wind instruments, and the latest generation of keyboard synthesizers is not only technologically advanced, but amazingly affordable.

On the other end of the spectrum is the market for tube-type amplifiers for guitar and bass. Despite the availability of sound modeling software and firmware for solid-state amps, no one has managed to capture the nuances of a tube-type amplifier. If you're into these kickbacks to the '60s and '70s, you know that the best — or at least most expensive — amps use point-to-point wiring. We're talking terminal strips, solder tabs, and discrete components — no circuit boards or chip carriers.

In the past few months, there's been an odd movement in the industry toward hand-wired and point-to-point circuitry. Everything from effects pedals to amplifiers and headphones are available with the "hand-wired" label. For example, take a look at the insides of my guitar effects pedal in the accompanying **photo**. It's an odd mix of directly soldered transistors and an op-amp IC with carbon composite resistors and a few caps.

Companies charge a premium for the hand-wired option. For example, the effects pedal in the **photo** sells for almost three times the price of the model based on a printed circuit board (PCB). Similarly, if you follow any of the big bands, you've probably noticed massive Marshall tube-type amplifiers on stage. While they use tubes, they also use modern PCB construction; in part to withstand the rigors of road work, and in part to reduce production costs through automated parts placement and soldering.

Marshall — along with Fender and other top-tier amplifier manufacturers — recently released a hand-wired line. You can expect to pay more for a one watt hand-wired tube-type Marshall amplifier than for one of their 100 watt professional amps you'll see on stage.

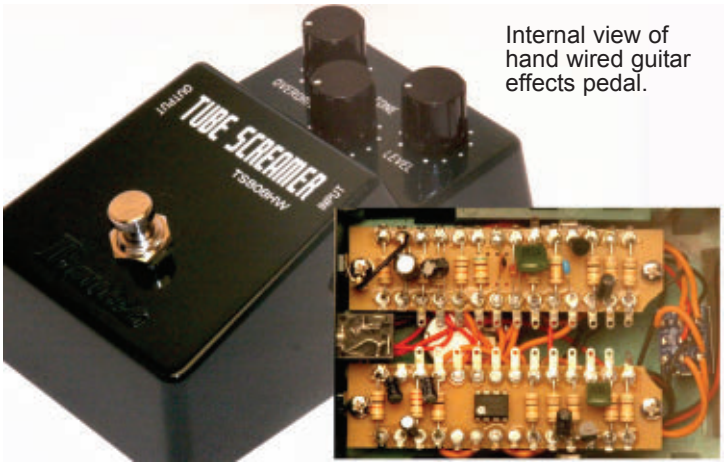
The marketing departments behind the hand-wired and point-to-point wired electronics emphasize the hand-wiring is performed domestically (in the case of Marshal, that means the UK). Supporting the local work force is certainly a good thing. However, they'd also have you believe that there's an audible difference in hand-wired electronics — something to do with the 3D arrangement of components and the interaction through the coupling this allows.

It's difficult to support or refute such claims because it's difficult to find devices that differ only in how they're wired. However, the effects pedal shown in the **photo** is available in both standard PCB and point versions. The components and schematics are theoretically identical.

So, I hooked up both pedals to a sound source and a spectrum analyzer. No difference. I tried the A/B switch on some musician friends who have trained ears. No difference. I even switched the "hand selected" op-amp — which was soldered in place — with the socketed op-amp from the standard effects pedal. No difference on the spectrum analyzer or to the ears of my musician friends.

Of course, I'm generalizing from one circuit, but the results make technical sense to me. Although there might be some coupling between components, at 3,000 Hz or so, the capacitive and magnetic coupling would be insignificant. I'm not saying products with hand-wired circuits aren't worth some extra money — they do tend to be higher in quality.

So, what's the relevance to you? Well, if you're looking to make some extra spending money, this might be a great time to offer "hand-wired" circuits to your musician friends. This is probably the only time in recent memory that you can compete with the overseas electronics



Internal view of hand wired guitar effects pedal.

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assembly industry from your basement.

You could offer audio cables with hand-wired connectors, or any number of DIY amplifier and effects circuits. I've even seen hand-wired replacement cables for studio-quality headphones listed for $200+ on eBay.

If you have an entrepreneurial bent, this might be the time to cash in on the fad. **NV**

Arduino made so simple, monkeys could do it.

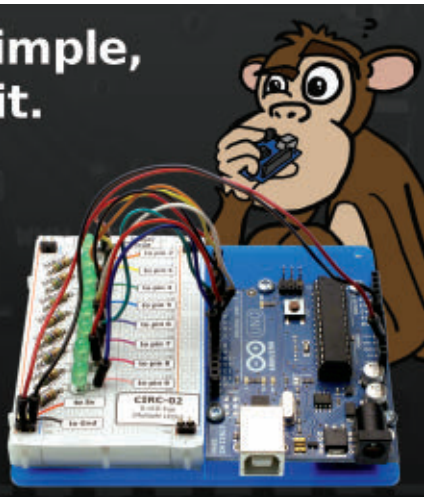
They actually tried to eat it, but it's still pretty darn simple.

The ARDX Kit is the most goof-proof way to learn using Arduino. Overlay templates show you where to plug components, and 12 experiments bring you up to speed, fast. It's *much* better than the other thing monkeys like to fling.

Price: **$84.95** SKU: **ARDX**

Coming soon: New 8-project add-on for your ARDX. Stay tuned!

PS: Chinchillas, though, are truly hopeless.



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TECH 2012 KNOWLEDGEY

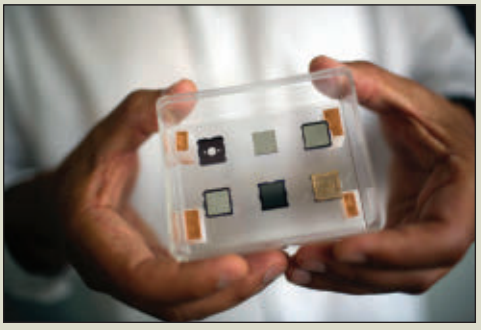
■ BY JEFF ECKERT

EVENTS, ADVANCES, AND NEWS

ADVANCED TECHNOLOGY

ION ENGINE FOR MINI SATELLITES

■ Components of MIT's mini ion thruster and assembled device (bottom right). *Photo by M. Scott Brauer.*

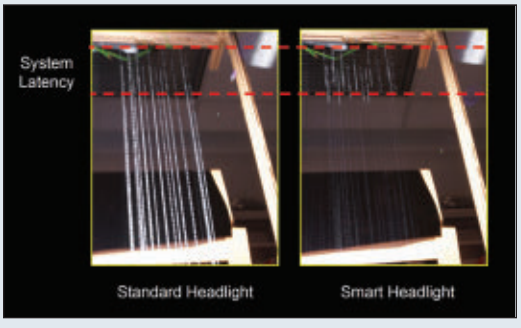


Most of the attention is garnered by big, sexy space projects like Mars exploration, but there are also a couple dozen little satellites known as "CubeSats" circling around up there. Conceived a little over a decade ago at Stanford University (**www.stanford.edu**) and Cal Poly (**www.calpoly.edu**), this breed of nanosatellite typically weighs no more than 1.33 kg and has a volume of 1 L (10 x 10 x 10 cm cube). Most carry only one or two scientific instruments and are deployed for various purposes by universities. An advantage is that because of their small and uniform size, they can be launched for less than $100,000 apiece. A disadvantage is that you can't fit a conventional propulsion system into one of them, so they just follow their fixed trajectory until they fall into the atmosphere and burn up.

However, a new type of propulsion system developed at the MIT Space Systems Lab (**ssl.mit.edu/newsite**) is likely to change all that. It is based on a small ion thruster device recently introduced by Prof. Paulo Lozano and his associates. The units measure only a square centimeter and 2 mm thick, so it would be possible to attach several of them to one CubeSat, thus providing controllable propulsion. Each thruster is covered with 500 microscopic tips that emit an ion beam when you apply a voltage, creating a puff of charged particles that shoves the satellite in the opposite direction. Each array produces only about 50 N of force, which wouldn't do much on Earth (about enough to move two mosquitoes). In space, however, it is sufficient to nudge a 2 lb satellite. According to Lozano, such a satellite outfitted with several microthrusters could "not only move to change its orbit, but do other interesting things — like turn and roll." Lozano predicts that microthrusters may even be used to power much larger satellites someday; flat panels lined with multiple thrusters could propel a satellite through space, switching directions by acting like a rudder. Is there a video? Sure: **www.youtube.com/watch?v=BHVkc2JwAuI**. Glad you asked. ▲

NOW YOU SEE IT, NOW YOU DON'T

■ Standard headlight vs. CMU's smart prototype.



Obviously, night driving requires a functioning set of headlights so you can see the road and other drivers can see you. Unfortunately, a heavy rain or snowstorm can quickly turn a pleasant drive down the interstate into a demolition derby, as the lights make raindrops and snowflakes stand out as bright, impenetrable streaks and make it difficult to spot danger that looms ahead. However, Prof. Srinivasa Narasimhan of the Carnegie Mellon Robotics Institute (**www.ri.cmu.edu**) thinks he has a solution. One of the professor's main areas of interest is the mathematical modeling of the interactions of light with materials and the atmosphere and — based on associated research — he has come up with a prototype smart headlight that is "capable of avoiding precipitation to improve driver visibility while adequately illuminating the road." The system is basically a collocated imaging and illumination arrangement that employs a projector, a camera, and a 50:50 beam splitter. The camera focuses on precipitation as it drops into the field of view; a processor predicts the future locations of the particles, then the projector cuts off illumination of the drops or flakes.

According to Narasimhan, the process takes only about 13 ms. The disillumination performance, of course, drops off with any increase in the precipitation fall rate, but tests have shown 63.4 percent accuracy at 10 mm/hr for snow, and 68.9 percent accuracy at 25 mm/hr for rain. Before the system can be implemented in the real world, it will need to be made faster and more compact. Simulations show that a system operating at about 1 kHz with a total system latency of 1.5 ms and a 1 ms exposure time should achieve 96 percent accuracy with 90 percent light throughput during a heavy rainstorm — assuming that the car is traveling at 30 km/hr (18.6 mph). Lower accuracy rates would still be pretty useful, though. A practical, compact system is expected in three to four years, with commercialization taking a few more years. ▲

Discuss this article in the Nuts & Volts forums at http://forum.nutsvolts.com.

COMPUTERS AND NETWORKING

LAPTOP/TABLET HYBRID INTRODUCED

■ HP's Envy x2 can shed its base to operate as a tablet.

If you are among the five or six people who were hugely disappointed when HP (**www.hp.com**) discontinued the TouchPad product line, you're in luck, sort of. The company has re-entered the consumer tablet market (sort of) with the Envy x2 hybrid laptop/tablet device. It starts out looking like a netbook, with a keyboard in its base and a 1366 x 768 pixel 11.6 inch touch display. You can yank the screen off the base, however, and use it like a tablet. In that mode, it is only 8.5 mm thick and drops from 3.1 lb to 1.5 lb. The convertibility means that the device needs two batteries: one in the base and the other in the tablet portion. You get eight hours of operation in the laptop configuration, but the company did not specify how long it will run as a tablet only. The Envy bridges the laptop-to-tablet gap by running Windows 8 which a Forbes reviewer described as "not a game changer," noting that the product line "is years late to market, short on apps, short on app developers, and short on giving anyone a reason to really create apps for Win8." In any event, the machine has 64 GB of SSD storage, the usual USB ports, an SD slot, a high-def webcam on the front, and an eight megapixel camera in the back. Price information is not available as of this writing, and delivery is slated for "the latter part of the holiday season this year." ▲

REVERSE IMAGE SEARCH

A pretty nifty variation on the standard search engine has been put forth by TinEye (**www.tineye.com**) which is described as a reverse image search engine. This is a great thing if you have a partial image and want to track down the whole one, have a low res image and want to see if a high res version is available, or just want to find out if your ex has posted those embarrassing pictures of you all over the Internet. Whereas other engines rely on things like keywords, watermarks, and metadata, TinEye uses image identification technology instead. All you do is provide a URL of the known image or upload it from your hard drive, and TinEye does the rest. The site crawls the Web looking for new images, but it also has contributions from Getty Images, iStockphoto, Wikimedia, and other sources. They presently claim to have indexed more than two billion images. Best of all, it's free to use for noncommercial purposes. Give it a try before Google comes up with a clone or buys the company. ▲

CIRCUITS AND DEVICES

HOW HIGH ARE YOU, REALLY?

■ STMicroelectronics' LPS331AP will enable accurate elevation readouts in handheld devices.

If you recently bought yourself a new GPS, you may have noticed that the elevation reading is not very accurate. In fact, you may even suspect that the unit is defective if you happen to be floating around at sea level but the unit says you're collecting sea cucumbers at the bottom of the Marianas Trench. It seems that this is normal, and the experts at Garmin (**support.garmin.com**) advise, "It is not uncommon for satellite heights to be off from map elevations by ±400 ft. Use these values with caution when navigating." Thanks, guys. The heart of the problem is that GPS units calculate elevation based on a mathematical model that roughly approximates the geodetic model of the earth and references altitude to this model. The earth doesn't usually match the model, so there you are. Or, probably aren't. The folks at STMicroelectronics (**www.st.com**) recently introduced the LPS331AP: a MEMS pressure-sensing device that can now allow a range of portable devices to accurately calculate vertical elevation relative to sea level with very high accuracy. According to the company, "This means that the mobile device will know not only on which floor of a building it is located, but almost on which step of the staircase." The sensor can accurately measure air pressure from 260 millibars (the typical air pressure at a height of around 6.2 mi higher than the summit of Mount Everest) down to 1,260 millibars (the typical pressure at 1.1 mi below sea level). Housed in a tiny 3 x 3 mm package and offering low voltage operation and ultra-low power consumption, the new device is well suited for smartphones, sports watches, and other portable equipment, as well as in weather stations and automotive and industrial applications. In fact, ST says it is already a component in an unnamed new Samsung smartphone. The device costs only $2.60 in manufacturing quantities, so look for it in the next generation of handheld devices. ▲

USB MAGNIFIER AIDS INSPECTION

■The MV200UM circuit inspection tool provides magnification up to 200x.

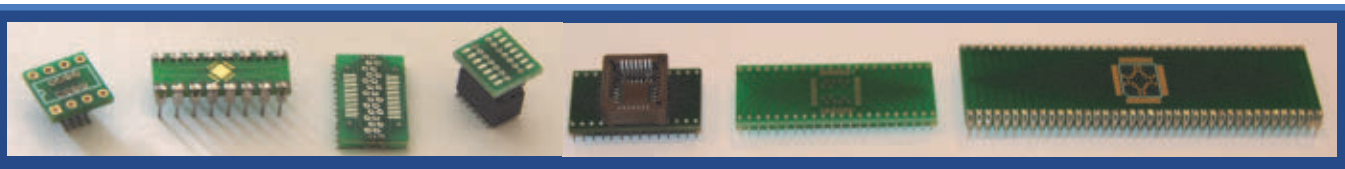
If you need to get a magnified view of your project, you can dig out a magnifying glass and flashlight from the drawer and take a look. An easier and more elegant way, however, is to use the new USB microscope/magnifier available from Saelig Co (**www.saelig.com**). The MV200UM is a two megapixel device designed for capturing magnified images and video for display on a PC using a standard USB 2.0 connection. With its built-in white LED illumination ring, it is said to be particularly useful for viewing circuit boards, tiny components, and markings; examining traces and solder joints on printed circuit boards; and detailed product examination and record taking, inspection, and quality control. You can obtain up to 200x magnification using a 1280 x 1024 resolution display, and the field of view can range from 1.9 x 1.5 to 82 x 65 mm. Moving images can be displayed at 30 fps, and free (Windows only) software allows snapshots, video recording, time-lapsed photos, and calibrated measurements. Not bad for $59.95. ▲

MAKE ANYTHING A SPEAKER

■The Rock-It 3.0 from OrigAudio.

My memory bone tells me that something like this — called a "contact speaker" — was popular many, many years ago. It was basically a garden variety speaker with the cone removed so that you could press it against a flat surface to generate sound. Just for fun, let's pretend like the Rock-It 3.0 device is actually new and innovative. According to the folks at OrigAudio (**www.origaudio.com**), all you do is attach the device to "literally anything" to turn it into a speaker. (The results are likely to be iffy, though, if you include things like palm trees, sides of beef, and Aunt Velma in the "literally anything" category.)

The input comes from an iPod or other musical device that has a 3.5 mm jack, and the Rock-It — powered by a rechargeable lithium-ion battery — amplifies the sound using a red Solo cup, cardboard box, garbage can, or whatever is handy. The sound quality varies according to what you use it with, of course, but it's pretty sure to be awful in any case. Maybe if you attached one to a speaker cone ... Only $34.99 at a store near you. **NV**



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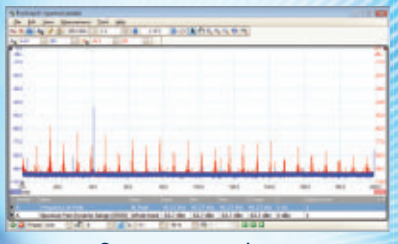
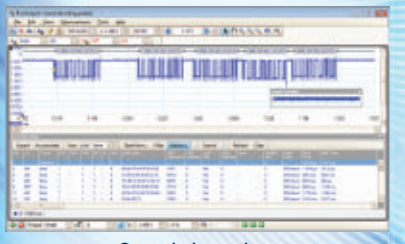
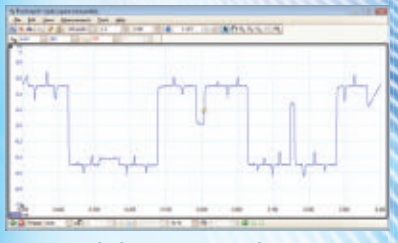


Spectrum analyzer



Serial decoding



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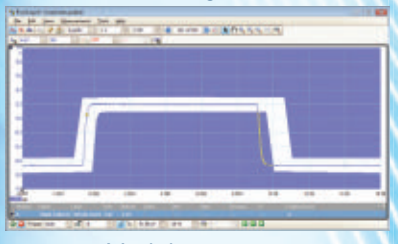
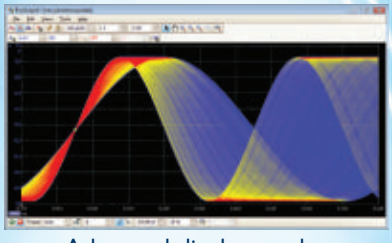
& function generator



Mask limit testing



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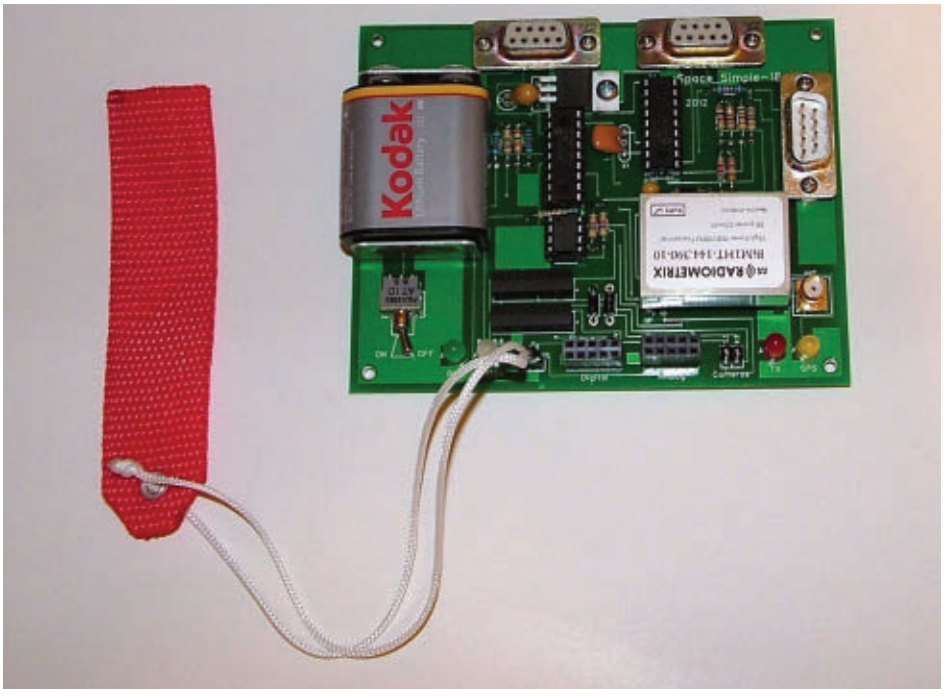
NEAR SPACE

■ BY L. PAUL VERHAGE

APPROACHING THE FINAL FRONTIER

A SIMPLER-TO-MAKE NEAR SPACE FLIGHT COMPUTER

With the improvements that Revolution Education is making in their M2 series of programmable microcontrollers, I thought it might be time to revisit my idea of an inexpensive near space flight computer. I selected the PICAXE-18M2 and designed it to run parallel to a standard APRS tracker — the TinyTrak 3. The result is a flight computer that operates experiments like cameras and sensors (both digital and analog), while being small enough to fit inside an insulated lunch box. It's called the NearSpace Simple because of its simplicity.



I designed the NearSpace Simple-18 flight computer in the hope that it will make it easier for amateur scientists to explore near space. However, before offering this flight computer as a kit, I would like to give *Nuts & Volts* readers the chance to make one for themselves. The design described here is nearly identical to the kit I plan to sell (within the practical limits of a single-sided PC board). I give *Nuts & Volts* readers permission to make one NearSpace Simple flight computer for themselves. I just ask that you don't go into business making and selling these to other people.

THE PRINTED CIRCUIT BOARD

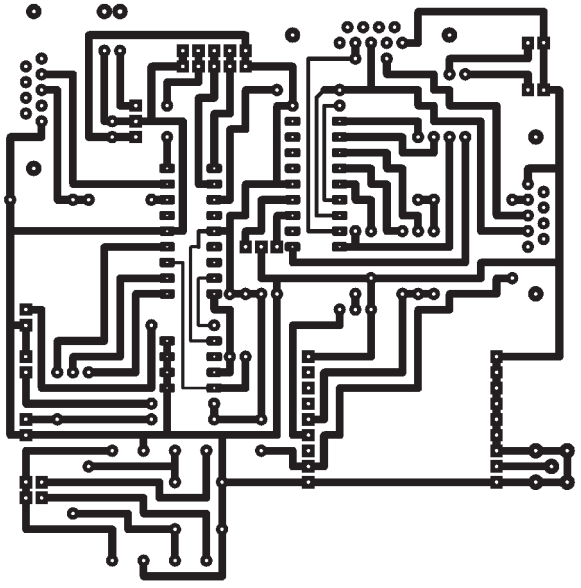
Figure 1 is a mask for making the PCB for the NearSpace Simple flight computer. It's a negative, so the black lines are the copper traces in the final board. Make a transparency copy of the image and transfer it to single-sided copper clad using your favorite method. For me, I prefer using DALPRO products along with sodium persulfate as the etchant. It's a clean and precise method for making prototype boards. You'll find DALPRO online at **www.dalpro.net**.

Discuss this article in the *Nuts & Volts* forums at http://forum.nutsvolts.com.

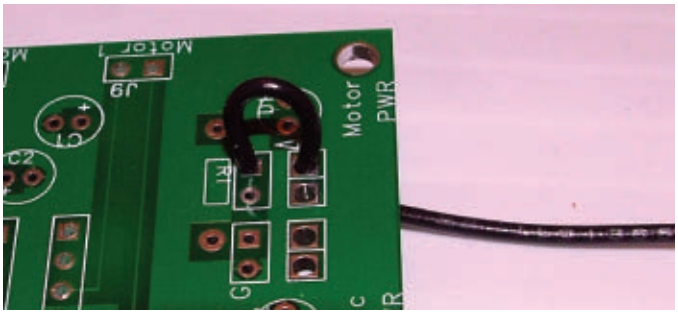
After etching your PCB, drill the holes for its electronic components. Most components will use a #64 drill bit. The voltage regulator (LM2940) will need slightly larger holes, as well as the SMA antenna connector. You'll need to be careful when drilling holes for the SMA connector because they are so large.

The drill bit used for the SMA connector is also used to make the strain relief holes for the power and ground wires. (The file is available at the article link.) This pair of holes provides strain relief for the power cable. As you can see in **Figure 2**, the ends of the wires solder to the PCB and pass through the larger holes in the edge (while still insulated) before they terminate in a connector for the battery of your choice.

By using this strain relief, you will ensure the power wires won't snap off the flight computer after a few uses. Broken wires can lead to a short circuit; if the loose wire happens to short out on the PCB or in the failure of the flight computer



■ **FIGURE 1.** The PCB for the NearSpace Simple flight computer measures 3.8 x 3.9 inches. You can use these dimensions to verify your transparency is accurate.



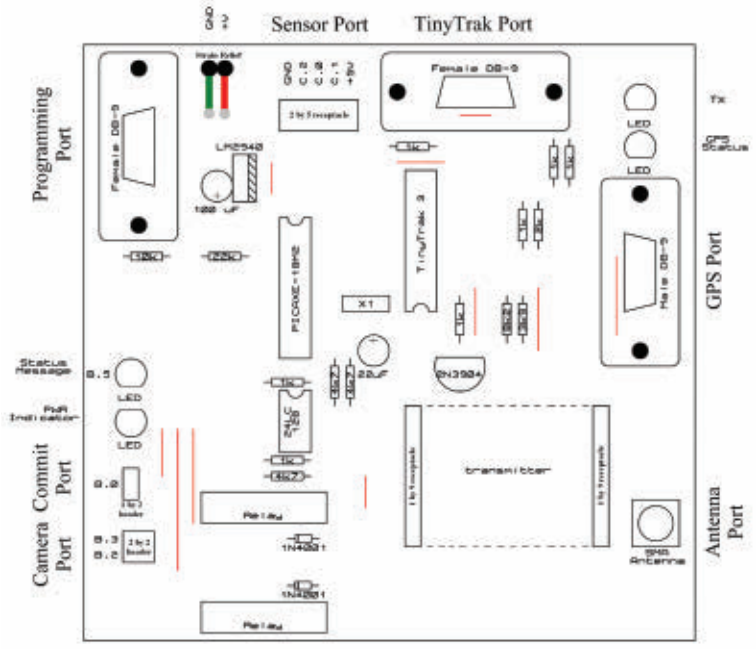
■ **FIGURE 2.** The strain relief takes the stress of flexing wires off their soldered connection. I'm surprised I don't see this more often in solder kits.

BUILDING THE FLIGHT COMPUTER

Here's a list of components you will need to complete the NearSpace Simple:

QTY	ITEM
2	1N4001 diodes
2	SIP relays (use Jameco item 1860088)
4	T1-3/4 LEDs
2	18-pin IC sockets
1	Eight-pin IC socket
1	PICAXE-18M2
1	TinyTrak 3 IC (purchase from Byonics at **www.byonics.com**)
1	24LC128
1	100 µF tantalum capacitor, six volts or greater (0.1" lead spacing)
1	22 µF tantalum capacitor, six volts or higher (0.1" lead spacing)
1	1 x 2 pin male header (0.1" lead spacing)
2	1 x 9 pin male header (0.1" lead spacing)
1	2 x 2 pin male header (0.1" lead spacing)
1	2 x 5 pin female receptacle (0.1" lead spacing)
1	Shorting block
1	10K resistor (1/4W)
1	22K resistor (1/4W)
6	1K resistor (1/4W)
3	4.7K resistor (1/4W)
1	2K resistor (1/4W)
1	8.2K resistor (1/4W)
1	3.9K resistor (1/4W)
1	10 MHz resonator
1	LM2940-5.0 (TO-220 form factor)
1	2N3904
2	Female DB-9 (PC mount)
1	Male DB-9 (PC mount)
1	SMA antenna connector (use Jameco part 145374)
1	Radiometrix BiM1HT-144.390-10 transmitter (or other frequency)*

*Radiometrix radios are available from Lemos International (**www.lemosint.com**). If the flight computer is to be flown in Europe, a different version of the transmitter with a different frequency and transmitter power level will be required.



■ **FIGURE 3.** Use this pattern as a guide for the placement of parts. The straight red lines are jumper wires. You'll find there are 10 of them — two of which are positioned beneath the DB-9 connectors.

during a mission, that's a good way to lose an expensive payload.

Finally, note that there are a pair of even larger holes for each DB-9 connector. These holes are used to bolt the wings of the DB-9 to the PCB prior to soldering it. They provide more structural support for the DB-9s than the solder pins. The large pair of holes for each DB-9 are marked in black in **Figure 3** and must be large enough to pass #2-56 bolts.

CONSTRUCTION STEPS

There is nothing particularly difficult about the construction of the flight computer. So, use **Figure 3** to help you locate the appropriate placement of each part. Begin construction by bending wires to form the jumpers needed to complete the connections on the PCB. DALPRO makes double-sided boards; however, I have found it easier to make a single-sided board with jumper wires than it is to make a double-sided board.

Next, bend the leads of the resistors into a staple shape and insert them into the appropriate holes. There are 15 resistors. Then, solder the two diodes (1N4001) in the same way. Watch the direction of the cathode band on the diodes when inserting them. The resistors and diodes lay flat on the surface of the PCB.

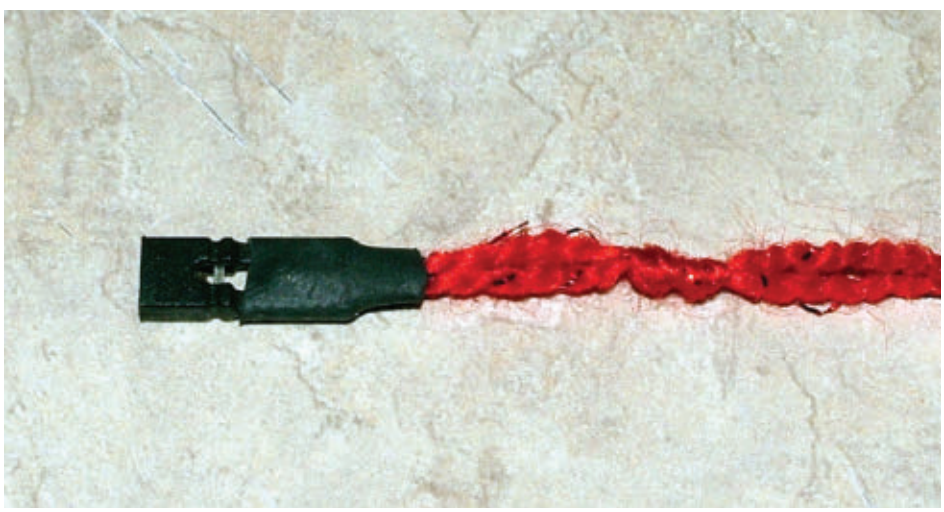
The next components are the IC sockets. Electrically their orientation doesn't matter, however, the notch in the sockets indicates the proper orientation of the ICs, and that is important. So, don't let the IC sockets mislead you by soldering them in upside down. Wait to put the ICs into their sockets until after everything is soldered and tested.

Now, solder the four LEDs. These are polarized devices, so make sure the cathode lead (usually the shortest lead and the flattened side of the LED body) is turned so that it lines up with the flat side shown in **Figure 3**. The SMA connector has hefty leads, so you'll need to crank up the heat a little bit to solder this item into place.

Now a word about the relays. These are also polarized devices because of their built-in protection diode. I added an additional diode into the circuit for each relay before I realized the relays contained diodes. However, I still recommend adding the 1N4001 diodes to further protect the relays.

Look closely at the relays and you will notice that their name and manufacturer is written on one face of the relay body in very pale lettering. That side of the relay must face the bottom of the PCB.

In other words, the lettering on the relays must line up on the same edge labeled relay in **Figure 3**. If the relay is soldered backwards, its protection diode will prevent it from working and cameras attached to the



■ **FIGURE 4.** I've used a piece of red yarn to create the Commit tag. After tying the yarn through the hole in the shorting block, I covered the knot and tab with a short length of heat shrink tubing.

flight computer will never record images.

The two capacitors are polarized devices and their positive leads must line up with the plus (+) symbol in the **placement diagram**. The voltage regulator (LM2940) and transistor (2N3904) are polarized devices and they are soldered as indicated. The hash marks drawn in the voltage regulator symbol represent the heatsink. Solder the 10 MHz resonator (X1) which is not a polarized device. The DB-9 connectors stand above the surface of the PCB.

Therefore, before soldering the DB-9s, use a pair of 1/2" long #2-56 bolts, nylocks (locking nylon nuts), and 1/4" long spacers, and bolt the DB-9s to the PCB. Now, solder the nine pins of the DB-9 connectors.

The Mission Commit port is a two-pin header. When a shorting block is plugged into this header, the PICAXE detects a logic low (connection to ground) on pin B.0. When the shorting block is removed, then the PICAXE detects a logic high, or five volts on pin B.0. You will use the shorting block to signal the flight computer to begin recording data. That way, you can power-up the flight computer while filling the balloon, and prior to launch.

This gives the GPS receiver enough time to acquire a position lock without the flight computer needlessly recording sensor data on the ground. I recommend tying a bright cord or ribbon to the shorting block as a reminder to remove it. Think of it as a "remove before flight" tag for your near spacecraft.

The Camera port is a 2 x 2 male header. Cameras with a bypassed shutter switch can be plugged into these ports and the flight computer will trigger them to record images. Any camera with a shutter consisting of a simple switch is suitable for the flight computer.

Cameras are bypassed by soldering two wires to the shutter switch and terminating them with a two-pin female receptacle. Once plugged in, the camera will sense a switch closure on its shutter switch when the flight computer closes a relay on the Camera port.

The Sensor port is a 2 x 5 female receptacle. This port permits three sensors — both analog and digital — to connect to the flight computer (at pins C.0, C.1, and C.2). Since the Sensor port also provides power and ground, sensor arrays are operational as soon as they are plugged into the port.

Finally, we have the radio transmitter. I strongly recommend against soldering the transmitter to the PCB. Instead, solder two 1 x 9 female receptacles to the PCB. This will allow you to remove the transmitter from the flight computer when it is not needed.

For example, the antenna is not needed while programming the TinyTrak and the PICAXE-18M2. Therefore, you are likely to remove the antenna from the flight computer because its length gets in the way while working with the flight computer at your PC.

It's a very bad idea to power-up the flight computer when the antenna is not attached to it. The resulting mismatching SWR will likely damage the transmitter if it attempts to transmit. By being able to remove the transmitter from its socket, the flight computer can be programmed on your workbench without worrying about damaging the transmitter.

That completes the construction. Next time, I will discuss testing and programming the flight computer. Afterwards, I plan to describe how to construct an airframe for the NearSpace Simple 18 from a lunch box. I think these three articles will be a good starting place for anyone interested in beginning a program of near space exploration.

Onwards and Upwards,
Your near space guide **NV**

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QUESTIONS & ANSWERS

WITH RUSSELL KINCAID

In this column, Russ answers questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. **Send all questions and comments to: Q&A@nutsvolts.com**

CHANGE RELAY TO LATCHING TYPE

Q I built a remote control unit from a kit and want to change the SPDT relay with a latching type. I am trying to control a pond pump and don't want to keep the transmitter and receiver on all the time the pump is running.

Would it be possible to replace RY12VDC with a latching type Omron MJN2K-DC12? I am not sure it would be worth the trouble.

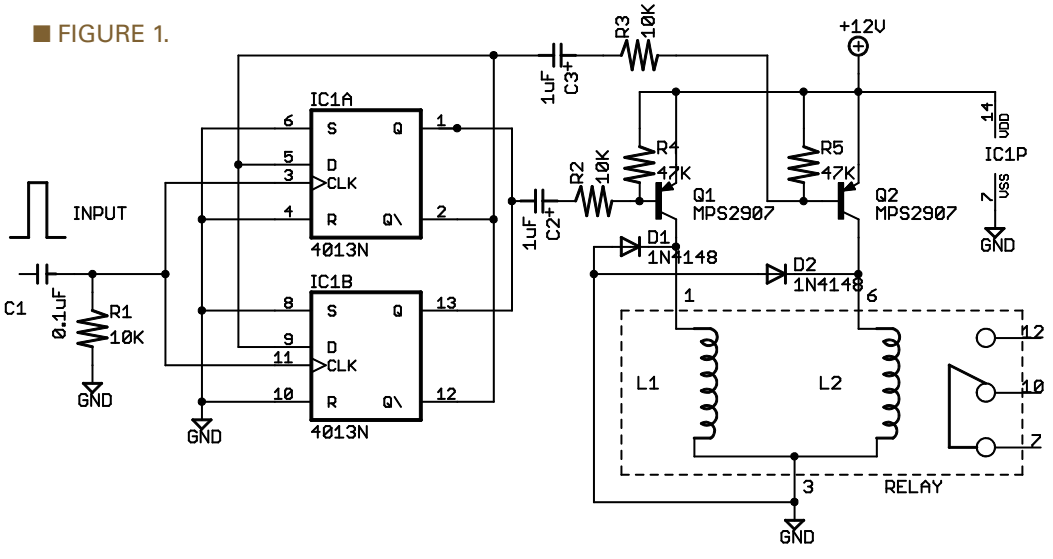
— Ken Bartone

A A latching relay is held closed by a permanent magnet. The magnet is not strong enough to pull the contacts closed, so a coil is energized to augment the permanent magnet. To open the contacts, either the current through the coil is reversed, or a second coil (wound opposite) is energized. I did not find the Omron relay that you mentioned, so I don't know if it was dual coil or not but I chose a dual coil type (Digi-Key part # Z834-ND, $7.23).

Figure 1 shows my solution. You can leave the original relay in place and take the signal from the transistor collector. Each time you energize and de-energize the transmitter, the latching relay will change states.

The coupling capacitors C2 and C3 keep the PNP transistors on just long enough to switch the relay and ensure that there is no current drawn in the steady state. The 4013 draws negligible current.

FIGURE 1.



SIX VOLT AUDIO AMP

Q I would like to build a sound system for my 12′ inflatable that I will mount under the seat. I have two 4 ohm 40 watt water resistant speakers, a BP10-6 (6V, 10 AH/20 HR) sealed maintenance-free rechargeable battery, and would use my iPod. I think all I need is a six volt amp to make this work. Do you have any ideas?

— Ken Brown

A I designed a simple linear audio amp which will give about 0.8 watts; you can see it in **Figure 2**. The maximum output is five volts peak to peak which converts to 1.77 VRMS; $1.77^2/4$ ohms = 0.78 watts. One channel is shown; you would use dual pots for the volume and tone to control two channels. The first stage is an op-amp with a gain of five; the second stage is a power amp with a gain of one.

More power output can be had using a full bridge power stage as shown in **Figure 3**. Both outputs are at VCC/2, so no output coupling capacitor is needed. Both outputs can swing nearly rail to rail which effectively doubles the voltage and gives four times the

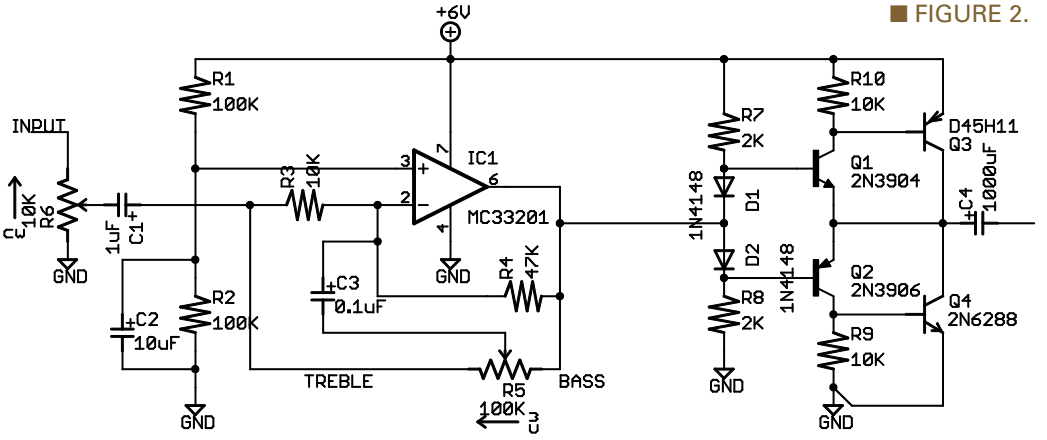
power. Another option is the TFA9815 class D stereo amplifier IC with 18 watts output; it runs on 12 volts. I don't know any that work on six volts. The datasheet has an application schematic; the Mouser part number is 771-TFA9815T/N1118.

PET-SAFE INVISIBLE FENCE

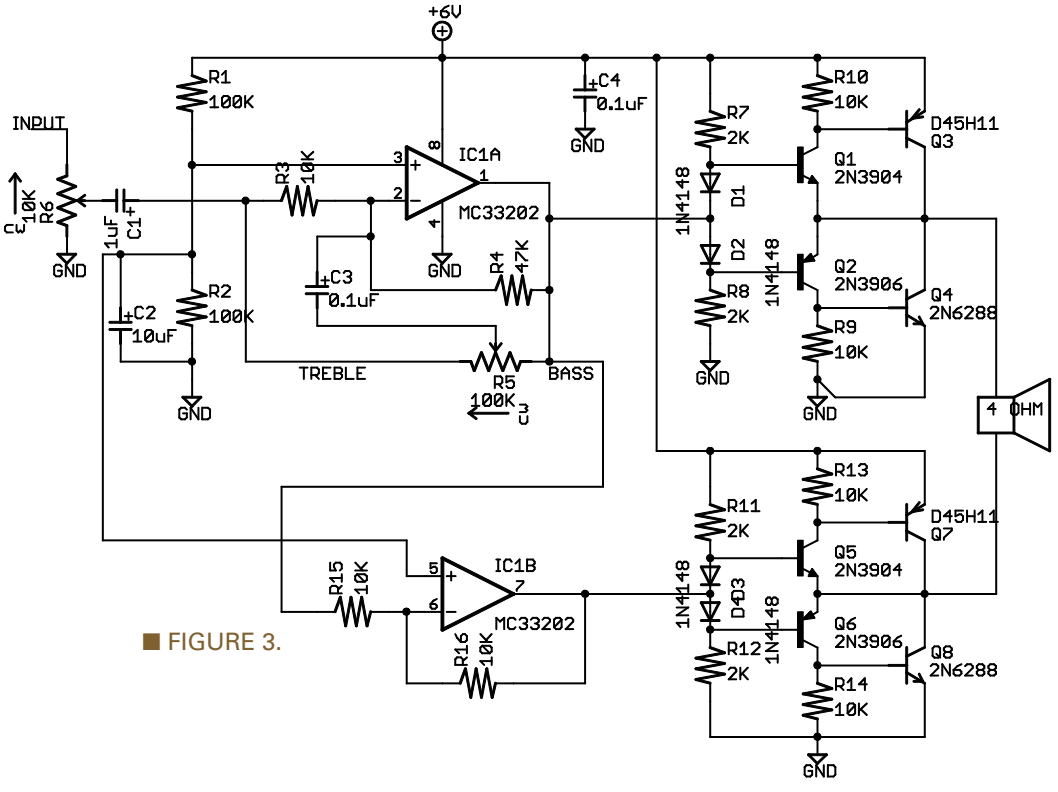
Q Can't get to my lab as much as I'd like to, and I haven't had any luck getting any info on some signals, so I'd like to get your help. I'd like to make a pet-safe invisible fence transmitter — something low level and adjustable — so I could make a room/area deterrent. Maybe an adjustable range for 10 to 20 feet; wall wart and/or battery powered.

I tried to reverse-engineer by analyzing a scope trace, but I couldn't get a good enough view to figure out what the signal is. Looked like some kind of modulated burst. Can you help?

— Kirt Chapin



■ FIGURE 2.



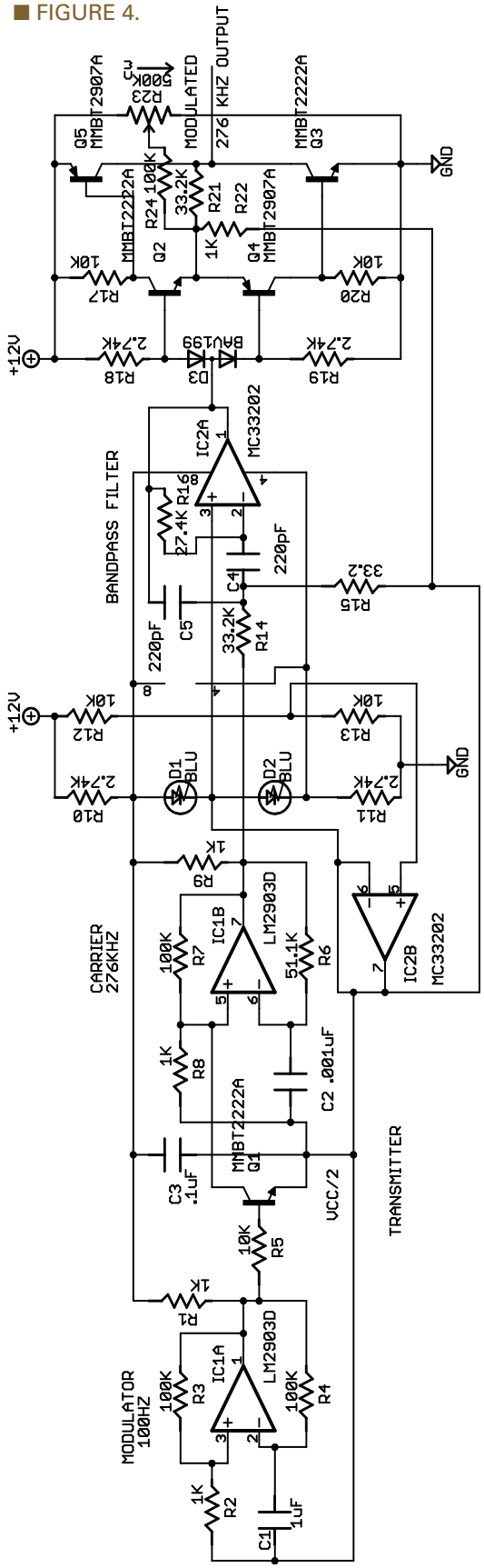
■ FIGURE 3.

A The antenna for this transmitter will be a long wire, so the frequency should be low. Otherwise, standing waves on the wire may cause unexpected results. I think 10 to 20 feet is too far; you want to have a defined perimeter and not box the animal in too much.

Ideally, the animal will feel a sensation within several feet of the wire which gets stronger as it gets closer — up to the "ouch" point. The system should not be affected by noise, so FM is preferred over AM. Simple tone modulation should be sufficient for security to prevent stray signals from affecting the pet.

Having thought it over, I don't see an easy way to make the signal to the pet vary with distance, so I am suggesting an AM transmitter and receiver. **Figure 4** is the transmitter. The transmitter is a square wave oscillator and square wave modulator, IC1A and IC1B, followed by a bandpass filter and driver. Putting square waves on the antenna could cause interference in your (and your neighbor's) TV; the bandpass filter output is a sine wave at 276 kHz, which should not be a problem for anything you have in the house. The modulation needs to be a low frequency that will cause painful muscle contractions. I think 100 Hz would be suitable.

■ FIGURE 4.



■ FIGURE 5.

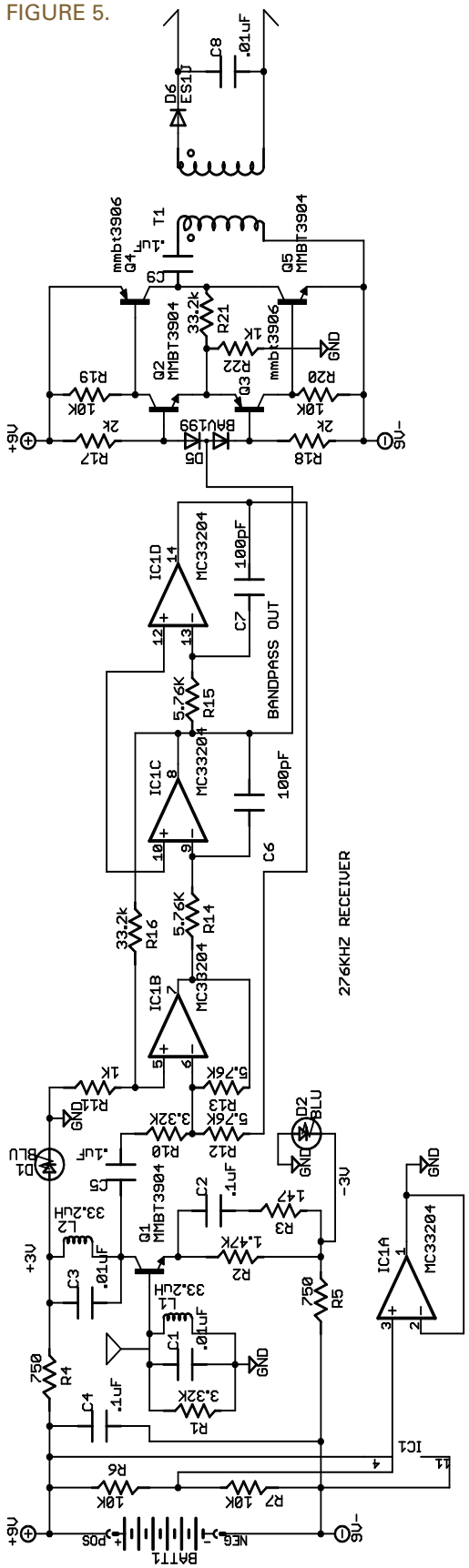


Figure 5 is the receiver. The power supply is a nine volt battery, but I find it easier to design using plus and minus supplies. So, I am using blue LEDs as voltage regulators. That gives me +3V and -3V supplies with VCC/2 as virtual ground.

Ground, after all, is just a wire; earth ground is a different symbol. The first stage is an L-C amplifier using Q1. The gain is set by R3 which can be tweaked if you need more or less. I assume L1 will be the antenna; more about that later.

The second stage is"state variable" topography; the three op-amp outputs are high pass, band pass, and low pass. I am using the band pass output which feeds a power amplifier.

The power amplifier drives a step-up transformer and rectifier that will provide enough voltage at low frequency to give a painful shock if the animal gets too close to the transmitter antenna.

I calculate that L1 should be 44 turns #30 on a one inch form, one inch long. You can spread or compress the turns to peak at 276 kHz. I think the coil should be vertical (at right angles to the antenna

wire) for the best effect.

If the signal is not strong enough just using the coil, you can add an antenna by winding wire around the collar. The other coil (L2) should be shielded from L1, or at least mounted at right angles to it.

L2 can be smaller; 79 turns #30 on a 1/2 inch form, one inch long. To be accurate, the winding should cover the full one inch length.

For the output transformer (T1), the transformer from a throwaway flash camera might work. Otherwise, a design based on Magnetics, Inc., core (F40506-UG pot core) would work.

Primary turns = 10 secondary turns = 111. The wire can be as small as #40 but that will be hard to handle, so use whatever will fit.

SOLAR PHONE BATTERY CHARGER

Q I backpack and I use my Droid Razr Max as a GPS to track my adventures. I am planning to go on weeklong expeditions, so I will need a method to power and recharge my Droid on the go.

I found panels (**www.voltaicsystems.com/3watt.shtml**) that are 3.4 watts at six volts, and six of them should get me ~20 watts of charging power in a 13.5" x 16.5" package that will mount on top of my backpack frame.

I want to charge a 10,000 mAh battery pack (four 'D' size NiMH cells = 5V), and power my USB ports from it.

Now, to electrically combine the panels I was going to put (low VD) diodes in series with each panel so that shaded cells don't short out the others. This may be overkill, and they will be introducing a voltage drop.

I thought about going back a few *N&V* issues and plagiarize parts of a charging circuit you had published and use UA7805 regulators to supply the USB ports, but that could overload the regulators, and five volts into a 7805 is less than five volts output from it.

Are the voltages from the panels, the battery, and the desired output too close to each other to work efficiently? There are commercially available units, but the watts per buck ratio is low.

The unit needs to be robust and fail safe, like using current-limiting circuitry instead of fuses. As well, a display showing charging current such as an LED bar graph would be nice, although more circuitry uses more power. This project is in the concept and design stage right now, so if you have better ideas, please feel free to express them.

— **Mark Hoffman**

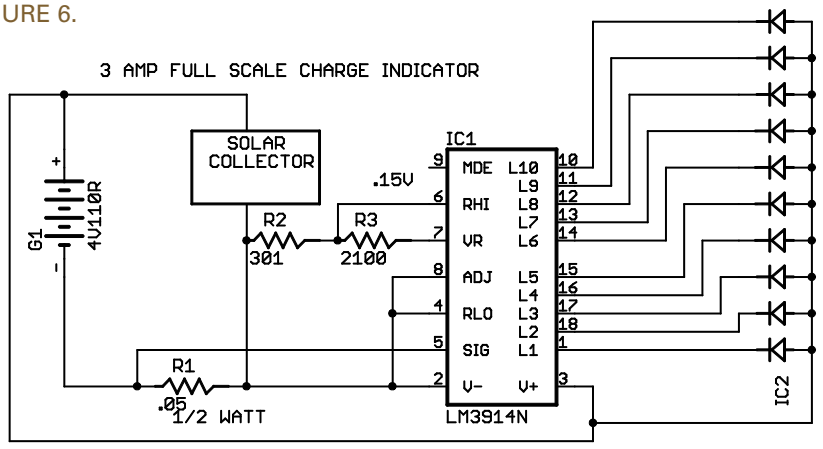
A Your phone has a 3.7 volt battery and an internal charging regulator, so all that is needed is to supply five volts or more to the phone. The solar cell is a diode itself, so you can parallel them without an external diode with no problem.

The solar cell you are contemplating claims to produce 1/2 amp at six volts in bright sun. Six of them can produce three amps and can charge the 10 amp-hour battery in four hours or less. The battery can maintain the phone for about five days (or more if you turn it off while you are sleeping), so there is little chance that you will run out of power.

Figure 6 is a three amp full scale ammeter to show charge rate. The circuit draws about 10 mA; only one or two LEDs are on at any time. Resistors R2 and R3 can be 1/8 watt, but R1 should be 1/2 watt because at three amps I^2*R = .45 watts.

Happy hiking!

■ FIGURE 6.



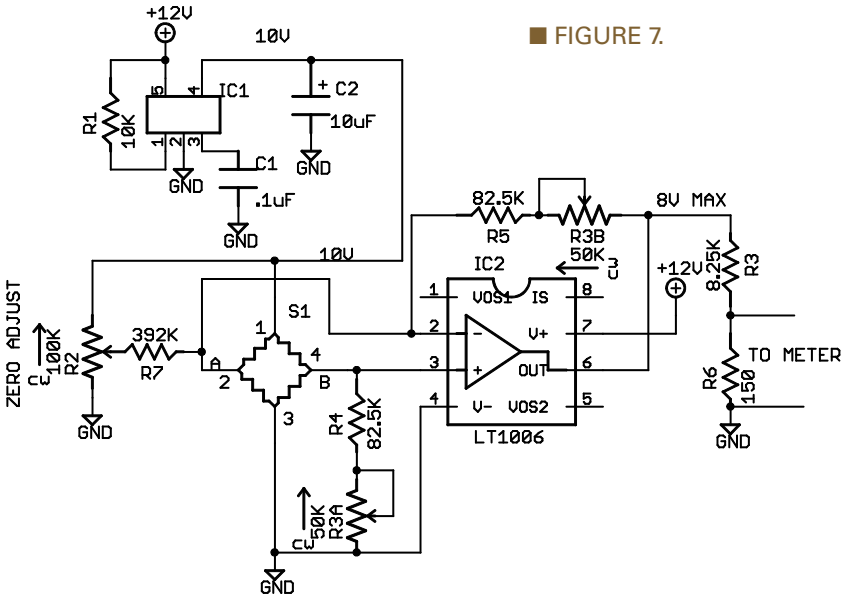
PRESSURE GAUGE

Q Would you please design me a circuit that would measure vacuum, and convert 0 to 15 PSI output to 0 to 200 MVDC? The circuit I would like to build is based on a Honeywell transducer (Mouser # 785-24PC15SMT). The transducer has an operating voltage of 10 volts DC nominal 12V max. I would also like to have a zero and span adjustment so I can calibrate it to the output value I need.

— **Jeff Miller**

A The sensor has two vacuum ports, P1 and P2, and two voltage outputs, A and B; see **Figure 7**. In this circuit, P1 will be the reference and P2 will be the vacuum. If you are measuring vacuum relative to ambient, P1 can be open.

The tolerance on span is ±30% and the DC offset is 30 mV max, so that is the range of adjustment in this circuit.



■ FIGURE 7.

The calibration varies directly with the applied voltage, so a good regulator is needed.

In **Figure 7**, R4 and R3A balance R5 and R3B such that when the voltages at A and B are equal, the op-amp output is zero volts or as close as the op-amp can get to zero. The voltage divider at the output will allow the meter to read less than 1 mV when the pressure (vacuum) is zero. Operating the circuit from ±5 volts will allow the output to be exactly zero.

In that case, R3A must be connected to ground, not to the minus supply. If the op-amp were rail to rail output, I would have run it from the regulated 10 volts, but ran it from 12 volts to insure that the output could reach eight volts.

It is important that R3A and R3B are equal in order to maintain balance in the circuit.

R6 is 150 ohms which will allow the output to be adjusted so the meter reads 150 when the vacuum is 15 PSI. If you want the meter to read 200 when the vacuum is 15 PSI, make R6 200 ohms. **NV**

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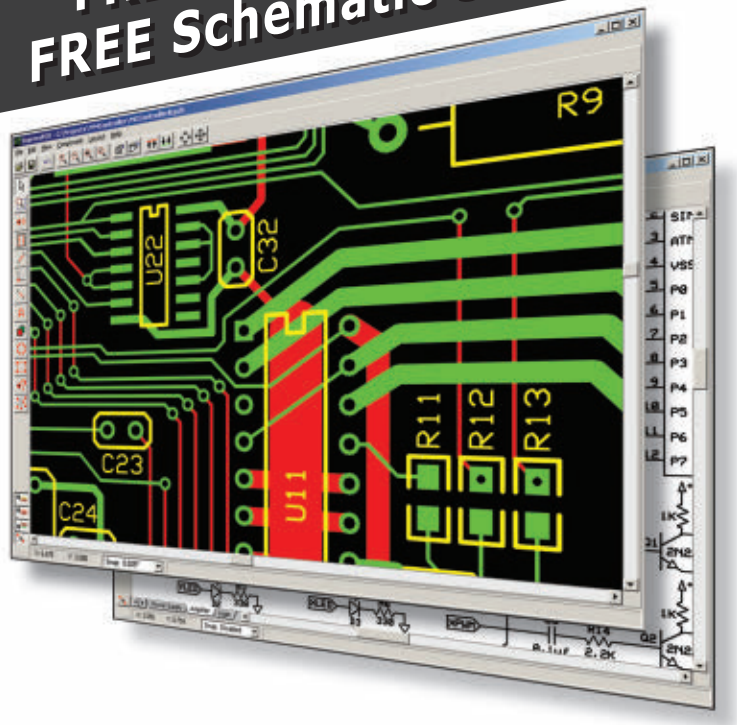

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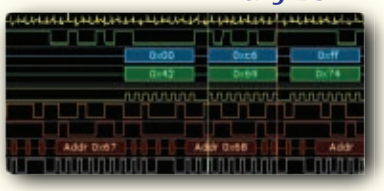

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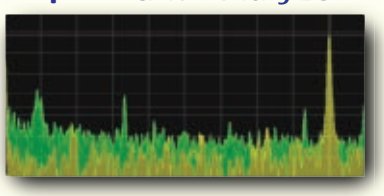

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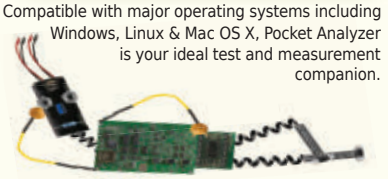

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NEW AND IMPROVED DECADE BOX

Global Specialties announces the release of two new and improved handheld decade box products to its line.

Model RDB-10 is a resistance decade box and model CDB-10 is a capacitance decade box. Both models are compact, convenient tools for aiding in engineering design and testing, as well as calibration of test equipment. They now come with a new and improved heavy-duty protective rubber holster. Both models also feature a tilt-stand for ease of use and viewing which is built into the new holster.

The RDB-10 offers seven decades of resistance, from one ohm to over 11 Mohm in one ohm steps. The CDB-10 offers five decades of capacitance ranges, from 100 microfarads to over 11 microfarads, in 100 microfarad steps. Compact (6" x 3.7" x 1.9") and light weight (0.95 lbs), the RDB-10 and CDB-10 are ideal for use in service, prototype, experimental, and educational applications.

Input terminals accept standard banana plugs, bare wires, spade lugs or alligator clips, and both models have a one year warranty.

The RDB-10 has a list price of $99 and the CDB-10 lists for $135.

Both models are available for immediate shipping from stock.

For more information, contact:
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PEDAL POWERED HEADLIGHT AND SMARTPHONE CHARGER

ECOXGEAR, by Grace Digital Inc., announces the ECOXPOWER pedal powered headlight and smartphone charger for bicycles. Equipped with a universal mount,

ECOXPOWER attaches to most standard and oversized hubs, and comes with a handlebar mounted, water resistant, and touch-screen compatible smartphone/GPS case. The ECOXPOWER is available for $99.99.

ECOXPOWER features an ultra-bright LED front headlight and red rear taillight that mount to a bike's front wheel hub. The included USB adapter cable runs up the front fork and into the handlebar mounted smartphone case.

As the front wheel of the bike turns, the ECOXPOWER's clutch engages between the tire's spokes, fueling a generator that powers the lighting system, the integrated lithium-ion rechargeable battery, and the power jack for a smartphone.

The smartphone case is touch-screen friendly, and accommodates all major GPS devices and smartphone models including iPhone and Android.

ECOXPOWER also comes equipped with an on/off remote switch that can be mounted to the handlebars, allowing for full control over the headlight and taillight while on a ride.

ECOXPOWER features include:

- Pedal powered ultra-bright LED front headlight and red rear taillight.
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STEAMPUNK PLANETARIUM CLOCK

By Geoffrey Gill

■ **FIGURE 1.** The Bolivian rosewood enclosure for my steampunk planetarium clock.

I have always had an interest in astronomy and bought my Celestron telescope in 1978. However, living in Michigan I was plagued by mosquito-filled summer evenings and frozen winter nights, so I began looking for ways to do my observing indoors at my convenience. I have also always been interested in the mathematics behind the motion of the planets, which have been known since the 17th century when Johannes Kepler published his *Astronomia Nova* which allowed the accurate calculation of planetary locations in the sky. In 1978, Jean Meeus first published *Astronomical Formulae for Calculators* which allowed these calculations to be performed on the programmable calculators of the day. Using these formulae, I can calculate the location of celestial objects using a microprocessor.

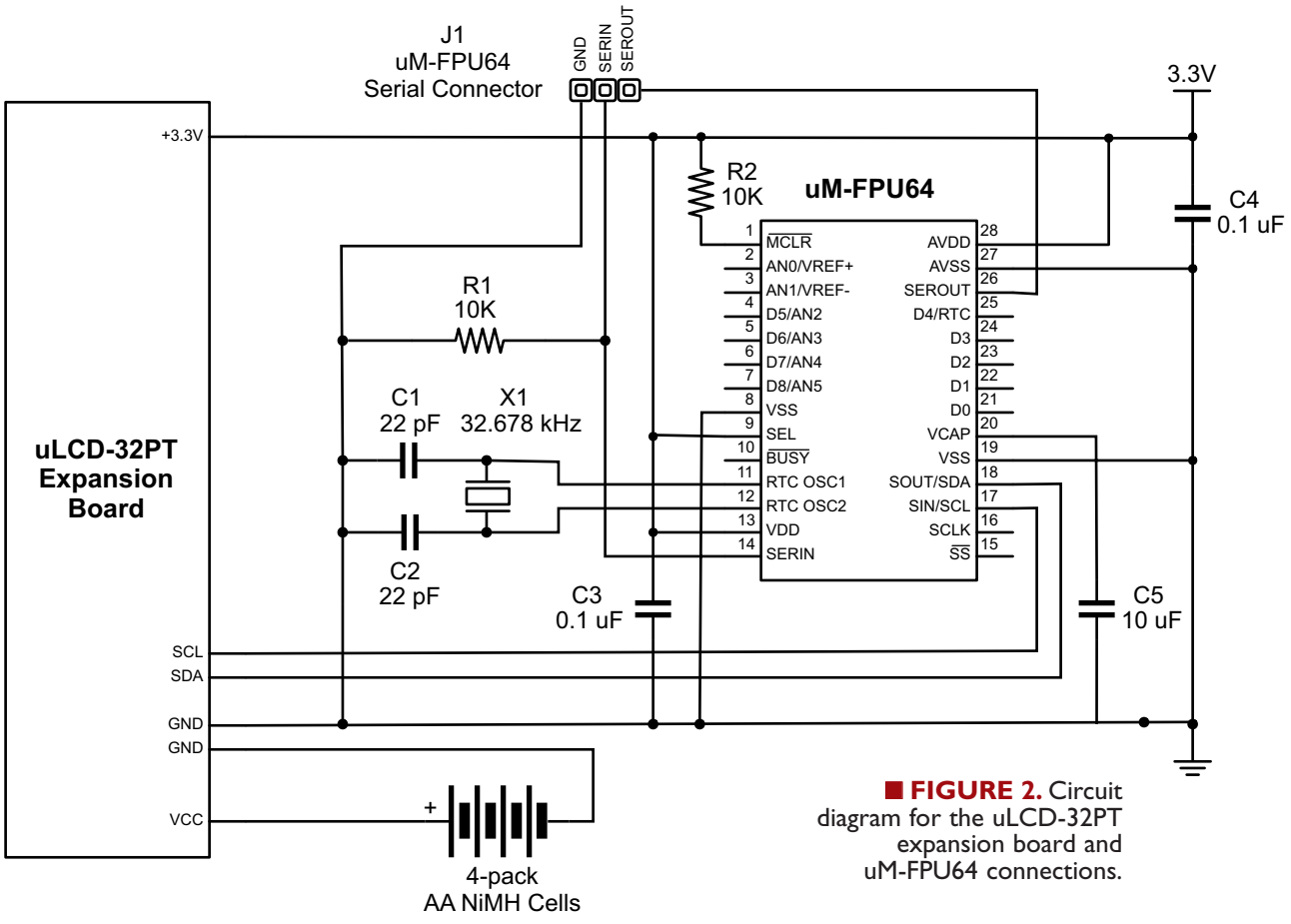
Yet another interest of mine is in steampunk technology and clocks. Thus was born my concept of a steampunk clock that would utilize a small LCD display to show the time in several formats — one of which is a planetarium view of the sky from my home in Las Cruces, NM. The planetarium part was the most interesting and complex, so that is where I'll start.

Getting Started

I saw an article in *Nuts & Volts* (April 2012 by Thomas Kibalo) that featured a product from 4D Systems in Sydney, Australia. I did quite a bit of research on their products and support before choosing the uLCD-32PT LCD display with integrated touch. It features a 320x240 QVGA display with 65K color depth per pixel. It also features 15K of program Flash memory, 14K of RAM, and a microSD card on the display board. A program in Flash can load programs from the microSD card into RAM, and execute them from there. The display is powered by their PICASO-GFX2 processor that features "soft silicon." It can be programmed to act as a stand-alone processor in GFX mode, or as a serial graphics display in SGC mode.

My original plan was to simply do all of the mathematics in the GFX mode, then display the stars, sun, moon, and five classical planets on the display. I soon realized that 15K of memory would be a serious limitation. The calculation of the positions of the sun, moon, and planets requires at least nine digits of accuracy to get even close to their true positions in the sky. Since the GFX language only supports integer math, this was going to be difficult.

Then, I remembered a product from Micromega Corporation in Kingston, Ontario. I had purchased



■ **FIGURE 2.** Circuit diagram for the uLCD-32PT expansion board and uM-FPU64 connections.

one of their uM-FPU V3.1 floating point math coprocessor chips several years ago. The uM-FPU can offload the math calculations from a microcontroller. It worked great, but since it only supported 32-bit floating point, it was limited to seven digits of precision. This past year, they announced their new uM-FPU64 chip with support for 64-bit floating point. Here was the answer to my problems.

The uM-FPU64 provides 15 digits of precision which would allow me to accurately perform the astronomical calculations. The bonus was that the uM-FPU64 has a built-in real time clock (RTC). It can be connected with either an SPI or I²C interface. I was quite familiar with the I²C interface from previous work with the Atmel ATmega, and it was also supported by the uLCD-32PT, so I was now ready to proceed with my project.

Putting the Pieces Together

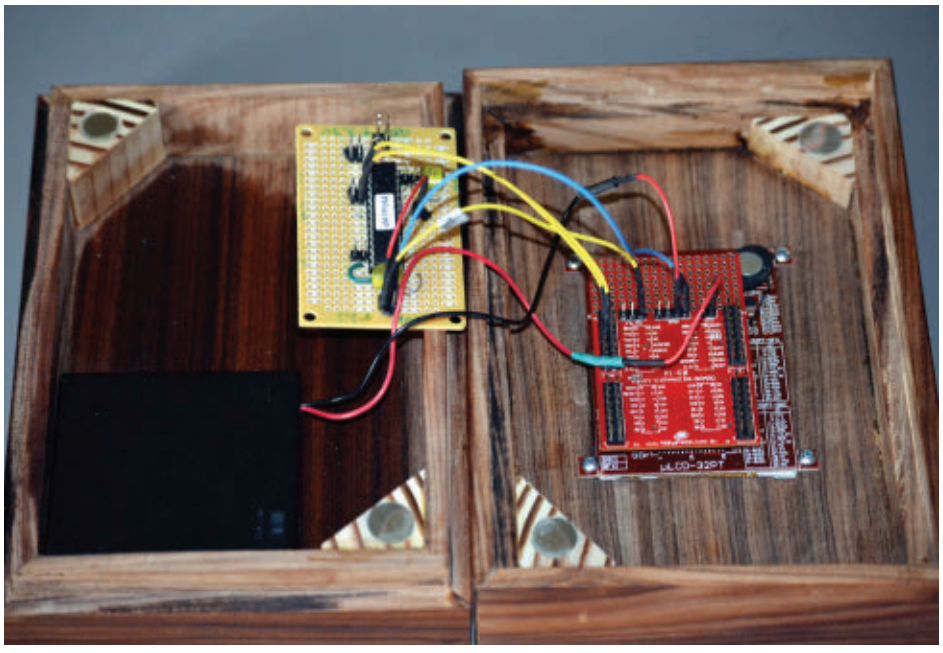
My objective for the steampunk clock was to have an attractive enclosure suitable for display in the living areas of my home, but any project box would work just fine. **Figure 1** shows the 5" x 7" x 2.5" box made from Bolivian rosewood that I had a local woodworker build. The uLCD-32PT is mounted on a carrier board with four tabs to hold it in place.

I purchased the 4D Systems expansion board which provides a convenient breakout of the two headers on the display board to a series of 0.1" headers that are easy to access. I also purchased their USB programming cable which allowed me to upload and debug programs to either RAM or Flash memory.

The GFX programming language is very "C like," so was easy for me to learn. The programming cable also provides 5V for powering the board ... I highly recommend this. The expansion board allows access to the I²C SDA and SCL signals and provides pull-up resistors. If you choose not to use the expansion board, remember to add pull-up resistors for the SDA and SCL signals.

The expansion board also provides access to 400 mA of 3.3V regulated DC, which is just what the doctor ordered for powering the uM-FPU64.

Figure 2 shows the schematic diagram of the circuit and **Figure 3** shows a view of everything connected. I used a printed circuit board (PCB) to mount the uM-FPU64 and a standard 32 kHz clock crystal for the RTC. I added header pins to provide power and to access the uM-FPU64 serial connection (for debugging) and the I²C connection.



■ **FIGURE 3.** The completed electronics mounted in the enclosure.

The documentation provided by both 4D Systems and Micromega is exceptionally clear. In addition, there are excellent forums and support available for both products. (The 4D Systems people in Australia never sleep!)

Finally, power is required when not using the USB programming cable, so a simple four pack of AA NiMH cells makes the entire unit portable with about six hours of run time.

Software

The remainder of the project involved software development, which took a couple of months of on and off work. It was very interesting and always challenging. The uLCD-32PT acts as the I²C master, sending commands to the uM-FPU64 and receiving the results of the calculations.

Early on, a decision had to be made as to how much information to display. Realistically, one does not want to try and display the entire visible sky because a lot of distortion would occur. I chose to show the view from Las Cruces looking south and ± 60 degrees to either side with a vertical range of +80 from the horizon. A series of calculations start from the current date and time.

At initial power-up, the date is loaded into the RTC using a simple keypad on the touch display as shown in **Figure 4**. After the initial setup, the current date and time is maintained by the RTC. Note that I chose to only work with dates from 2000 to 2099.

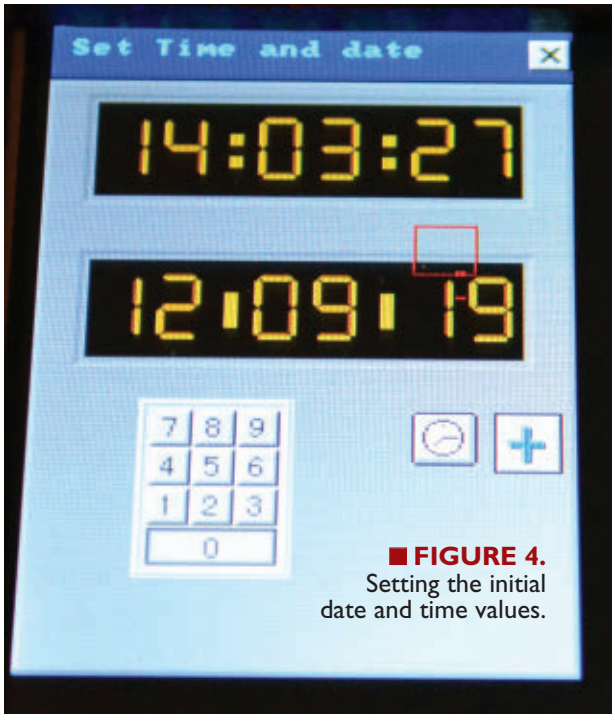
The mathematics will accommodate dates and times from ~4000 BC to 3000 AD, so you could easily extend it if you wanted to see the sky as the Spanish missionaries saw it from Las Cruces in the 1600s.

The JulianDate function stored on the uM-FPU64 calculates the Julian Date at 0 hrs Greenwich Mean Time (GMT). GMT is used to avoid the vagaries of daylight savings time. From there, a second function is used to calculate T, the time in centuries since Jan 1, 1900 — a value that is used in many of the following calculations.

The uM-FPU64 has 4 KB of Flash memory to store your functions. I used the same programming cable from the uLCD-32PT to program and debug the uM-FPU64 functions. A third function calculates the sidereal time at Greenwich at 0 hrs GMT. Sidereal time reflects the fact that the earth's revolution on its axis does not correspond with the same view of the sky at the same time each day.

This results in the progression of the constellations that are visible in the different seasons of the year. Orion, for example, is a nighttime constellation during the winter in the northern hemisphere, but is not visible in the evening sky in the summer.

The STatGact and STatLC functions calculate the current sidereal time at Greenwich and then at Las Cruces, NM. The latitude and longitude of Las Cruces are stored in the uM-FPU64 Flash memory, but future modification could allow for those to be entered using the touch



■ **FIGURE 4.** Setting the initial date and time values.

Sample Code

This code sample shows part of the calculations for determining the position of the moon. It gives you an idea of the many astronomical calculations that are being performed on the uM-FPU64. Full code files are available for download at the article link.

```
; calculate the geocentric longitude of the moon
;-----------------------------------------------
MoonGeoCentLong = MeanLMoon +
6.28875*SIN(MeanAnomMoon)
                    +
1.274018*SIN(2*MoonMeanElong-MeanAnomMoon)
MoonGeoCentLong =
MoonGeoCentLong+.658309*SIN(2*MoonMeanElong)
                    + .213616*SIN(2*MeanAnomMoon)
MoonGeoCentLong = MoonGeoCentLong/360
MoonGeoCentLong = FRAC(MoonGeoCentLong)*2*PI

; calculate the geocentric latitude of the moon
;----------------------------------------------
MoonGeoCentLat =
5.128189*SIN(MeanDisMoonNode)+.280606*SIN(MeanAno
mMoon+MeanDisMoonNode)
MoonGeoCentLat = RADIANS(MoonGeoCentLat +
.277693*SIN(MeanAnomMoon-MeanDisMoonNode)
                    + .173238*SIN(2*MoonMeanElong-
                    MeanDisMoonNode))

; convert to right ascension and declination
;-------------------------------------------
A = SIN(MoonGeoCentLong)*COS(OblEcliptic)-
TAN(MoonGeoCentLat)*SIN(OblEcliptic)
B = COS(MoonGeoCentLong)
RA = ATAN2(A,B)

DEC = ASIN(SIN(MoonGeoCentLat)*COS(OblEcliptic)
      +
COS(MoonGeoCentLat)*SIN(OblEcliptic)*SIN(MoonGeo
CentLong))
```

Please note that in Jean Meeus' book, all equations are in degrees, but the uM-FPU64 uses radians in all trigonometric functions, so conversion from degrees to radians is required. The uM-FPU64 includes instructions for converting between radians and degrees.

display, or even read automatically from a GPS receiver.

It is easy to change the longitude and latitude constants to your own location or any other location on earth. Note that for ease of calculations, most constants are stored in radians rather than degrees, minutes, and seconds.

The real work is done in the AltAz function where the altitude and azimuth are calculated. The altitude and azimuth give the location on the display, as well as the direction you should look to see the object of interest.

In order to calculate which stars are visible, their right ascensions and declinations must be known. I decided to use the microSD card to store that information. A quick search found the HYG database which is a compilation of stellar data from a variety of catalogs, and contains star names, positions, brightnesses, distances, and spectrum information. I used a spreadsheet program to narrow this extensive listing down to the 500 brightest stars and eliminated everything except the star name, right ascension, declination, magnitude, and color. The spreadsheet also converted all degrees to radians for ease of use in the astronomical calculations performed by the uM-FPU64.

I stored this list as a text file on the microSD, which is read and parsed by the uLCD-32PT program. The corresponding data for each object is sent to the uM-FPU64 and the display coordinates are returned. There are some additional mathematics that correct for the projection of a sphere onto a planar display, and I set aside some codes in the color field to be used to draw constellation lines if you wish to.

Once the screen coordinates and magnitude are returned to the uLCD-32PT program, a decision is made regarding visibility on the display. If an object is visible, it is plotted with the correct color and some adjustment in diameter based on the magnitude. The file is read and each star is plotted as it is read, until the end of the file is reached. Once the stars are displayed, additional functions are called to calculate the right ascension and declination of the sun, moon, and other classical planets. The calculations for the moon are very intense. According to Jean Meeus, "In order to

PARTS LIST

ITEM	SOURCE
uLCD-32PT(GFX) 3.2" LCD with touch	MicroController Pros; **www.microcontrollershop.com**
P1-EB expansion board	MicroController Pros
4D programming cable	MicroController Pros
uM-FPU64 floating point coprocessor	Micromega Corporation; **www.micromegacorp.com**
Printed circuit board	RadioShack #276-150
X1 32.768 kHz crystal	Mouser #732-C002RX32.76K-APB; **www.mouser.com**
C1, C2 22 pF ceramic capacitor	Mouser #581-SR152A220KAR
C3, C4 .1 µF ceramic capacitor	Mouser #581-SR215C104K
C5 10 µF tantalum capacitor	Mouser #581-TAP106M025SCS
R1, R2 10K 1/8W resistor	Mouser #291-10K-RC
J1 0.1" header	Mouser #538-22-28-4301
Four pack AA NiMH battery pack	Various sources

■ **FIGURE 5.** A planetarium view of the sky from my home in Las Cruces, NM.

calculate an accurate position of the moon, it is necessary to take into account hundreds of periodic terms in the moon's longitude, latitude, and parallax."

SOURCES

4D Systems Pty Ltd
www.4dsystems.com.au

Micromega Corporation
www.micromegacorp.com

HYG Database
www.astronexus.com/node/34

Astronomical Formulae for Calculators
4th edition;
by Jean Meeus
www.willbell.com/math/index.htm

I decided to include only some major perturbations, and sacrifice some accuracy. See the sidebar for some sample uM-FPU64 code. The function to calculate altitude and azimuth screen coordinates is again called for each planetary object and the object is plotted if visible. Labels are also shown for the planetary objects. Finally, a set of 30 degree spaced coordinate altitude and azimuth lines are plotted on the screen for reference. **Figure 5** shows a picture of the LCD screen with the planetarium view.

Wrapping Up

This project turned out to be very successful and very rewarding. Additional plans include putting more constellation lines onto the microSD card which is a simple process and does not require anything more than adding lines to the spreadsheet containing the star data.

Some changes to extend the battery life could be made. Turning off the graphics display and putting the uM-FPU64 into sleep mode would lengthen battery life.

A backup battery for the uM-FPU64 would allow the RTC to keep time while the main battery is removed for charging. You can certainly customize your own Steampunk planetarium clock so you can gaze at whatever stars your heart desires. **NV**

Special thanks to Cam Thompson at Micromega Corporation, for the impetus to write this up and critical edits.

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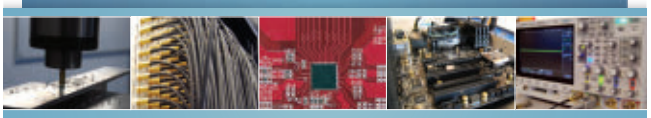

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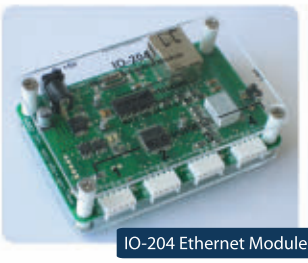

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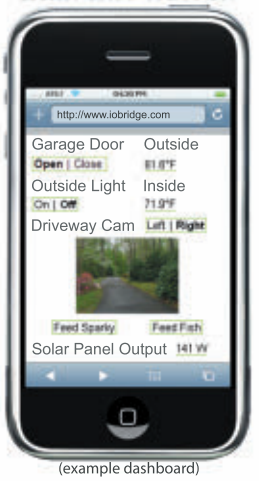

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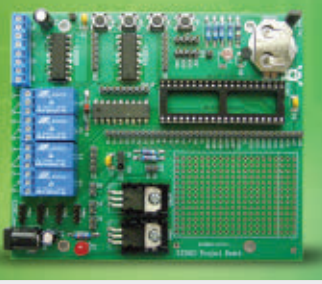

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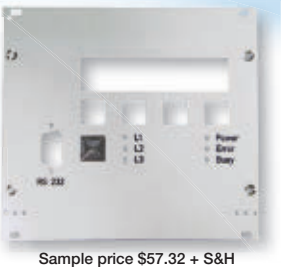

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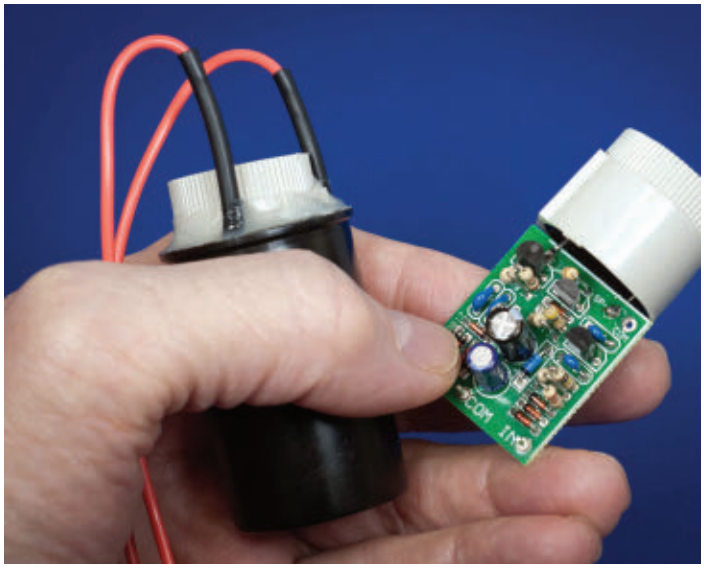
BUILD THE CHIRPER — THE BEST TURN SIGNAL MONITOR EVER!

By Mike Huddleston



This little device solves one of the most aggravating and potentially dangerous aspects of driving a car (or riding a motorcycle) — inadvertently leaving a turn signal flashing while traveling down the highway. In many cases, the driver just doesn't know it's on and may drive for miles with his turn signal flashing, confounding other drivers and compromising driving safety. Why? Because the driver can't hear the turn signal beeper. The simple fact is if the manufacturer's turn signal alarm volume is tolerable when the car is stopped, it's probably too soft to be heard over road noise at 70 mph. If it's powerful enough to be heard at highway speeds, it's uncomfortably loud when idling at a traffic stop.

The device described here provides an obvious solution: It emits a relatively quiet 'click' when the turn signal is first activated and you're sitting at that stop sign; then, in about 30 seconds, it escalates to a truly attention-getting mega-CHIRP, easily heard at highway speeds and sure to motivate the driver to cancel the turn signal. It's a simple, inexpensive, one-evening project suitable for the novice builder.

I decided to create this gadget for my vintage motorcycles, although the problem exists with any vehicle with turn signals. The turn signals on early bikes don't automatically cancel, so they continue to flash until the rider (me) remembers to turn them back off (which I frequently forget to do). So, the goals of this project were:

1. Effectively solve a real problem.
2. Be easy for the novice builder to construct (i.e., no surface-mount parts).
3. Be inexpensive.
4. Include no microprocessors or other sequential digital devices that might be corrupted by the nasty electrical environment in a vehicle.
5. Have a foolproof design (as much as possible).
6. Be easy to install.

How Turn Signals Work

Conventionally, turn signals are straightforward. When the switch (the lever on the steering column) moves to connect either the right or left signals, the flasher provides a slow square wave (about 1 Hz) to all the bulbs on that side of the circuit, and they all flash in unison. When the steering wheel swings back from the turn, a mechanical linkage returns the switch to the 'off' position. There are some safety processes built in. For example, if a bulb has burned out, the flasher runs faster to signal the driver that something's amiss. The beeper may be part of the flasher circuit or (more often) another circuit connected to this one. The Chirper's two wires connect between the 'left'

and the 'right' hot leads whether at the switch itself, at the front or rear bulbs, or anywhere in between.

Circuit Explanation

The key to the Chirper's operation is pretty simple. The Mallory Sonalert® alarm sounder used will emit a 'click' if it's energized for a really brief period — say two milliseconds — and an ear-piercing shriek if it's left on continuously. The 'chirp' comes about when it's on for about a tenth of a second. So, the Chirper drives the Sonalert with 2 ms pulses for about 30 seconds for the clicks, then transitions to 80 ms chirps.

The circuit is wired such that one of its leads goes to the hot lead of the left turn signal bulb itself, and the other to the hot lead of the right bulb, as shown in **Figure 2**. This way, current will flow from the 'on' lamp, through the circuit, to ground through the 'off' lamp. This makes for an easy installation, but the Chirper has to manage the reversing polarity on right and left signaling. Hence, the bridge rectifier.

Referring to **Figure 5**, when either of the turn signal inputs is activated, about +13 volts is applied to one input while the other is at zero volts. As the signal flashes on, about +12 volts appear across R1, and nearly instantaneously pop C1 to about +11 volts through D5. (Internal voltage measurements are referred to the circuit common — 'COM' on the schematic; NOT the vehicle's ground.) C1 is large enough so that its charge will stay at nearly +11 volts while the turn signal cycles through

FIGURE 1. Typical conventional automobile, truck, and motorcycle turn signal circuit.

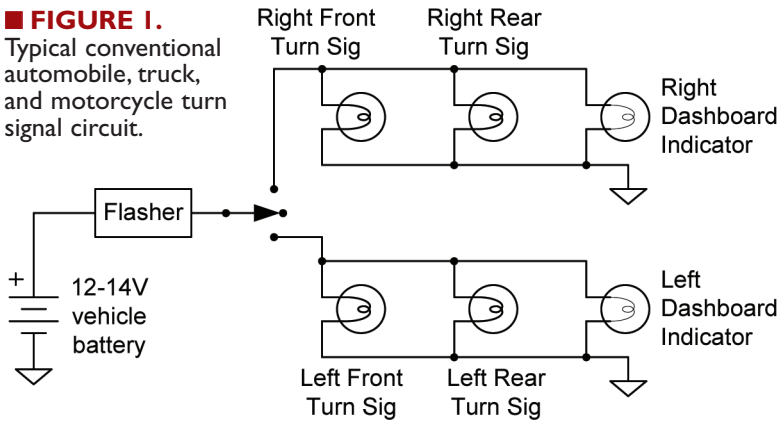
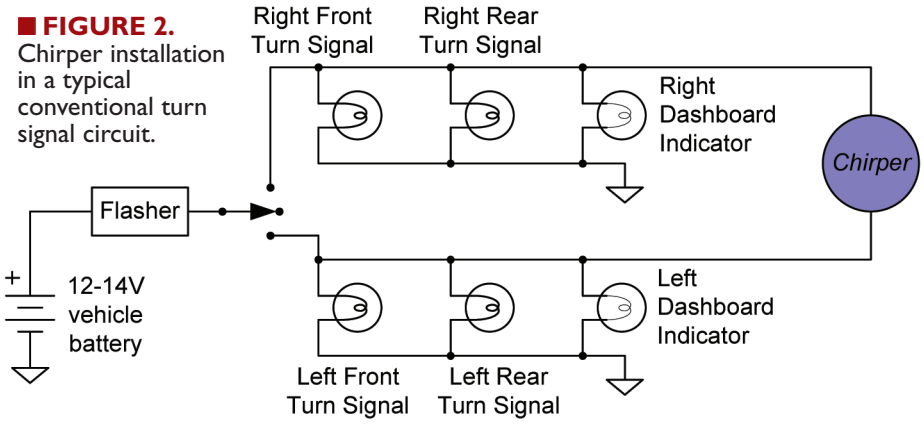
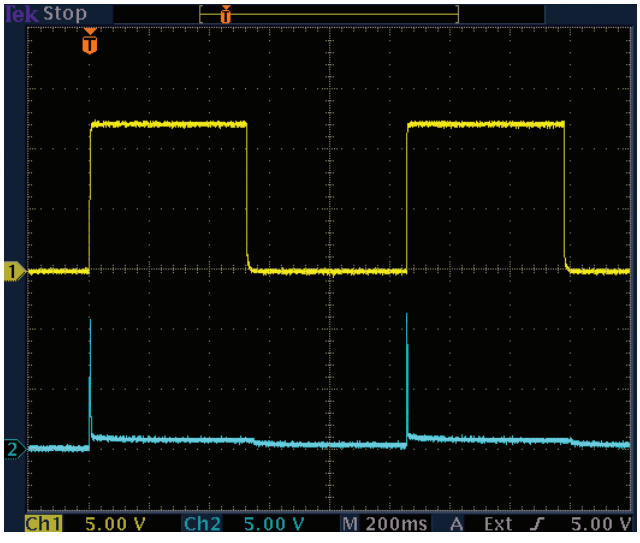
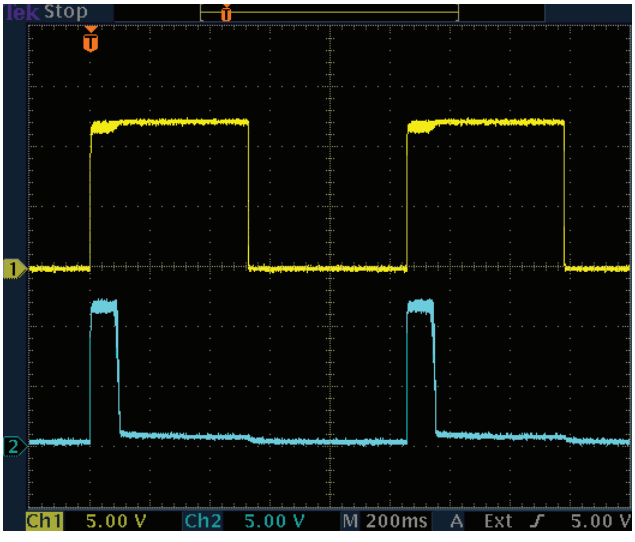


FIGURE 2. Chirper installation in a typical conventional turn signal circuit.



FIGURES 3 and 4. Clicks — 2 ms pulses — on the left, compared to the chirps — about 80 ms — on the right. Top trace in both is the vehicle's flasher output driving the turn signal bulbs. These are two second scans.





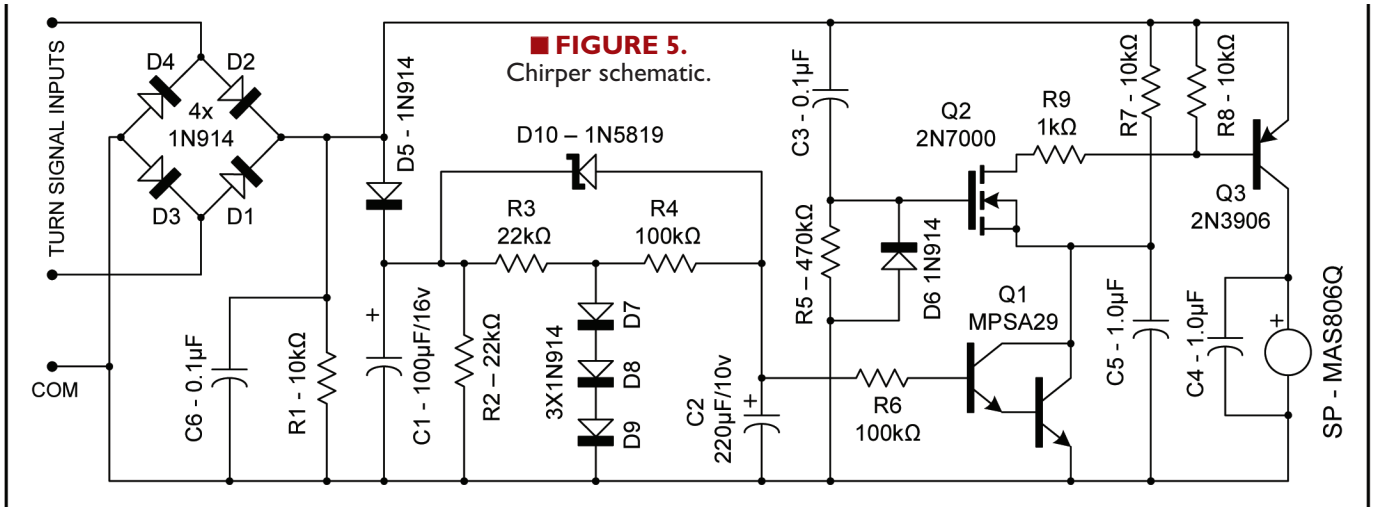


FIGURE 5. Chirper schematic.

its on-off-on-off cycle, although it is constantly discharging slowly through R2 and R3. C1's only job is to keep some positive current flowing through R3 in order to maintain the 2.0 volts on the regulator formed by D7, D8, and D9. This regulated 2.0 volts also experiences a 'pop' — a practically instantaneous transition — from 0V to 2.0V when the turn signal is first engaged.

The integrator made up of R4 and C2 determines the time delay before the clicking turns to chirping. With the component values shown, it's around 30 seconds, but that can be reduced by decreasing the size of R4 and/or C2. Conversely, click-to-chirp time can be lengthened by increasing those component values.

Q1 is an NPN Darlington transistor that switches on when the voltage across C2 climbs to about 1.3 volts — around 30 seconds from the first turn signal flash. When Q1 turns on, its collector voltage drops to about one volt. The Darlington transistor was chosen for its high gain, its high input impedance, allowing a smaller C2, and its higher V_{BE} (around 1.3 volts), so the switching threshold voltage is higher and more manageable than with a single transistor at about 0.65V.

Meanwhile (as shown in **Figure 7**), the differentiator formed by C3 and R5 provides an exponential +12V pulse for about 80 ms each time the turn signal flashes on. (The corresponding negative pulse is swallowed by D6.) This positive pulse is applied to the gate of Q2 — an N-channel enhancement-mode MOSFET used as a logic AND gate. Q2 conducts when the pulse on its gate is high *and* its source — connected to Q1's collector — is low (when Q1 is saturated). Then, Q2's drain will sink Q3's base current for about 80 ms each time the turn signal flashes and produce the 80 ms chirp. Q3 is a PNP bipolar transistor that provides the drive current for the sounder. R8 keeps Q3 turned off until Q2 switches it on.

R7 and C5 create the click sound on each flash during the 30 second

FIGURE 6. Voltage across C2 (bottom trace) gradually rising as a result of the turn signal (top trace). Q1 turns on when this voltage hits about 1.3V. This is a 40 second scan.

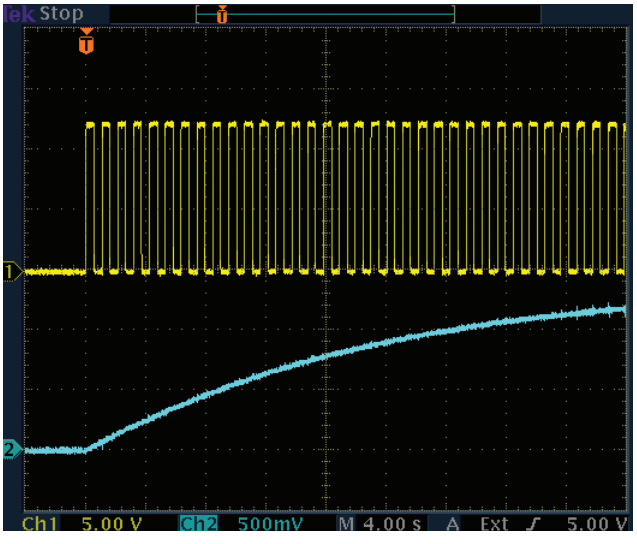
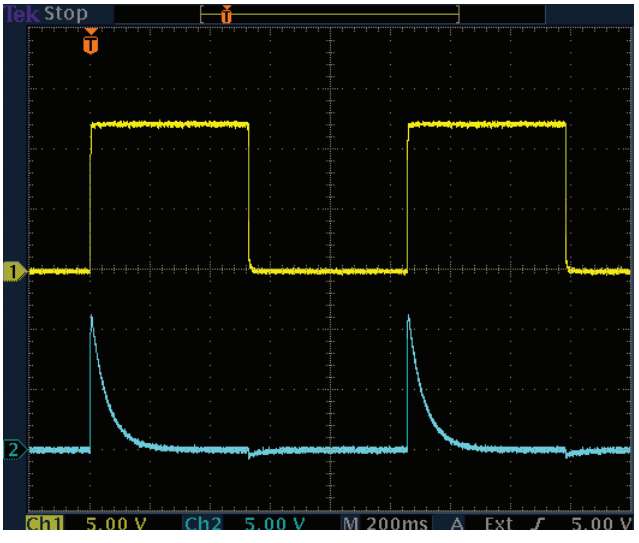
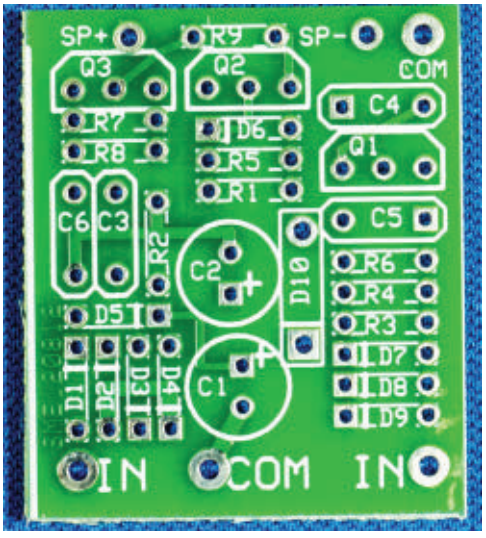
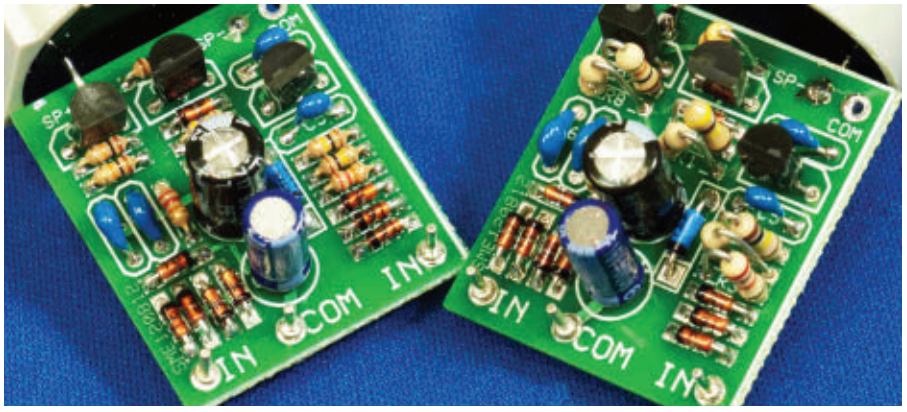


FIGURE 7. C3-R5 differentiator creating a pulse to apply to the Q2 gate as a result of the input square wave. This is a two second scan.





■ **FIGURE 8.** The bare circuit board.

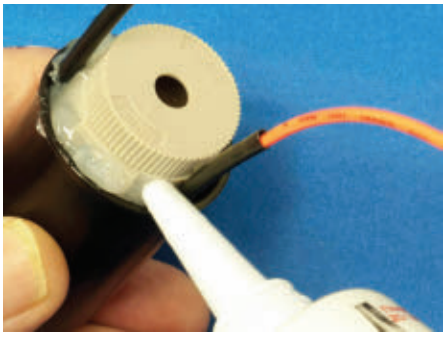


■ **FIGURE 9.** Two completed PCBs. The one on the left uses 1/8 watt resistors and the other has 1/4 watt units. Note the method of alternating 1/4 watt resistors so they don't short.

delay before Q1 turns on. This works as follows: During the click-to-chirp delay period, the C3-R5 differentiator still creates the 80 ms pulses to Q2's gate each time the turn signal flashes, but since Q1 is off, Q2 can't pull Q3's base low to energize the sounder. However, C5 holds Q1's collector low for a short period — about 2 ms — when the lamp first switches on; this causes a 2 ms low pulse to Q3's base, producing a sharp click from the speaker. Note: If the clicks are too loud, C5 (1.0 µF) may be replaced with a 0.1 µF capacitor. This shortens the click pulse to about 400 µs, softening it considerably. This is a good solution for quiet cars.

When the turn signal is cancelled, the circuit no longer 'sees' the input pulses, so C1 begins to discharge relatively quickly through R2 and R3, while C2 discharges very

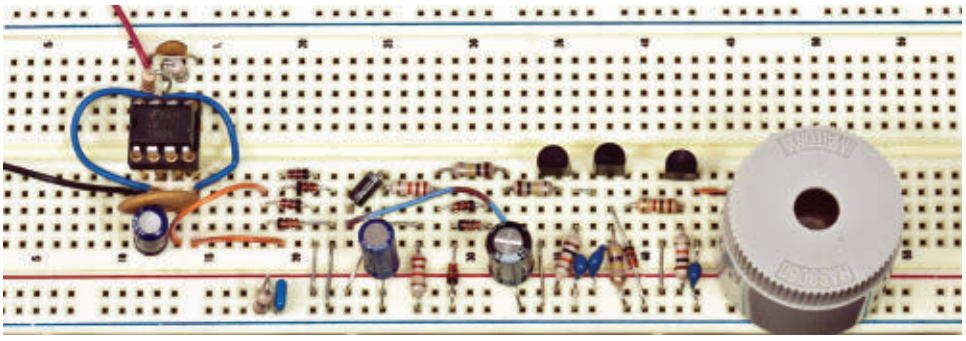
■ **FIGURES 10, 11, and 12.** Use clear silicone caulk to anchor the PCB in the film can, then apply a moisture seal around the Sonalert unit.



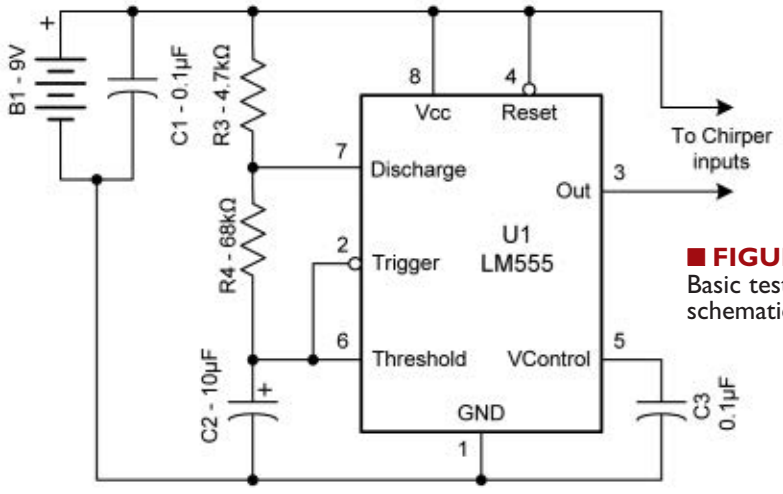
PARTS LIST FOR CHIRPER

ITEM	VALUE	DESCRIPTION	DIGI-KEY PART #	EA.*	TOTAL*
C1	100 µF/16V	Electrolytic capacitor, 0.1" lead spacing	P5138-ND	0.22	0.22
C2	220 µF/10V	Electrolytic capacitor, 0.1" lead spacing	P5518-ND	0.30	0.30
C3, C6	0.1 µF/50V	Disc capacitors, 0.2" lead spacing	445-5258-ND	0.29	0.58
C4, C5	1.0 µF/25V	Disc capacitors, 0.2" lead spacing	445-2857-ND		
0.43	0.86				
D1-D9	1N914	GP silicon switching diode	1N914BCT-ND	0.10	0.90
D10	1N5819	1A 40V Shottkey diode	1N5819FSCT-ND	0.50	0.50
Q1	MPSA29	Darlington NPN transistor TO92	MPSA29RLRPGOSCT-ND		
0.33	0.33				
Q2	2N7000	N-channel enhancement-mode MOSFET TO92	2N7000FS-ND	0.42	0.42
Q3	2N3906	PNP GP transistor TO92	2N3906FS-ND	0.20	0.20
R1, R7, R8	10 kΩ	1/8 watt, 5% tolerance leaded resistors	CF18JT10K0CT-ND	0.09	0.27
R2, R3	22 kΩ	1/8 watt, 5% tolerance leaded resistors	CF18JT22K0CT-ND	0.09	0.18
R4, R6	100 kΩ	1/8 watt, 5% tolerance leaded resistors	CF18JT100KCT-ND	0.09	0.18
R5	470 kΩ	1/8 watt, 5% tolerance leaded resistor	CF18JT470KCT-ND	0.09	0.09
R9	1 kΩ	1/8 watt, 5% tolerance leaded resistor	CF18JT1K00CT-ND	0.09	0.09
SP	MAS806Q	Mallory Sonalert®	458-1057-ND	6.92	6.92
Total Component cost					$12.04

*Prices at time of printing. Prices may have changed.



■ **FIGURE 13.** Basic test circuit on the left, and Chirper circuit on the right.



■ **FIGURE 14.** Basic test fixture schematic.

slowly through R4. However, when C1's voltage drops below C2's, the Schottky diode D10 goes into conduction and provides a path for C2 to discharge through R2 in about 15 seconds. If the driver re-engages a turn signal before C2 is fully discharged, the click-to-chirp delay will be less than 30 seconds. Note: Just about any low current Schottky diode can be used for D10. If unavailable, a germanium diode is a pretty good replacement. A silicon diode isn't as good due to its higher forward voltage drop, but is better than nothing.

Additional notes: R1 is used as a constant load on the input circuit to make sure the circuit snaps off quickly at the end of a flash, and provides a discharge path for C3 and C5. C6 is a noise filter across the power supply. C4 tunes the Sonalert and makes its output louder.

Construction

There is nothing difficult or critical about the construction. There are no digital parts, so voltage transients — common in motor vehicles — will have minimal effect. No microprocessors, so no programming. Just solder the parts together as shown in the schematic, and you should be successful. The Chirper can be built on perfboard or a printed circuit board (PCB). I made a PCB that would fit inside a 35 mm plastic film can, as shown in this article.

There's nothing magic about building this; the only caution is to carefully observe polarity on the diodes and electrolytic capacitors, and to use a tiny soldering iron tip. This is a compact unit and the pads are close together, so watch carefully for shorts. Final assembly is then into a plastic 35 mm film can for protection; 35 mm film cans are becoming less common, but any drug store still sells 35 mm film. It makes a small enough package to be fitted unobtrusively under the dash in a car or in a motorcycle's battery compartment. Be sure to waterproof the can with clear silicone caulk (but leave the speaker hole unsealed!).

Substitutions. It's okay to substitute 1/4 watt resistors for the 1/8 watt units, but since there's not enough room for them to lie down on the PCB, they must be mounted standing up. Q1 can be MPSA12, MPSA13, etc. Q2 can be 2N7001, 2N7002, etc. Just make sure the pinouts don't change if you use the circuit board. The circuit board is available from vendor mike.h on eBay.

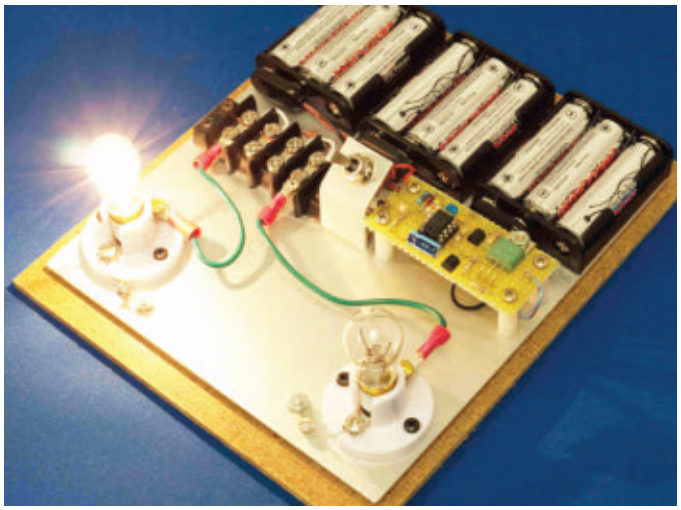
Installation

One of the Chirper's design

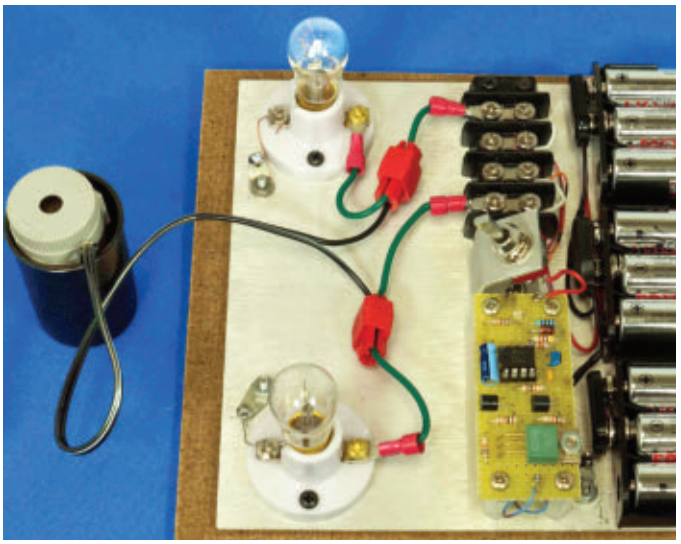
PARTS LIST FOR BASIC TEST FIXTURE

ITEM	VALUE	DESCRIPTION	DIGI-KEY PART #	EA.*	TOTAL*
B1		9V battery	P647-ND	1.98	1.98
		9V battery clip	BS6I-HD-ND	0.61	0.61
C1, C3	0.1 µF/50V	Disc capacitors	445-5258-ND	0.29	0.58
C2	10 µF/25V	Electrolytic capacitor	445-2857-ND	0.43	0.43
R3	4.7 kΩ	1/4 watt, 5% tolerance leaded resistor	S4.7QCT-ND	0.08	0.08
R4	68 kΩ	1/4 watt, 5% tolerance leaded resistor	S68KQCT-ND	0.08	0.08
U1	LM555	IC timer (industry standard)	LM555CNFS-ND	0.43	0.43
Total Component cost					$4.19

*Prices at time of printing. Prices may have changed.



■ **FIGURE 15.** Demo board.



■ **FIGURE 16.**
Shows the Chirper connected with the in-line wire taps.

goals was simple installation. Normally, only two wires are necessary: one connected to one of the right turn signal lamps, and the other wire to one of the left turn signal lamps. It works equally well on either negative- or positive-ground systems (if you have one of those classy old English sports cars). Installation is simple and straightforward, but the details depend on the target vehicle. I installed them on my three motorcycles as follows:

1978 BMW R80/7 — Replaced the original sounder (sounded awful) under the seat. Works great.

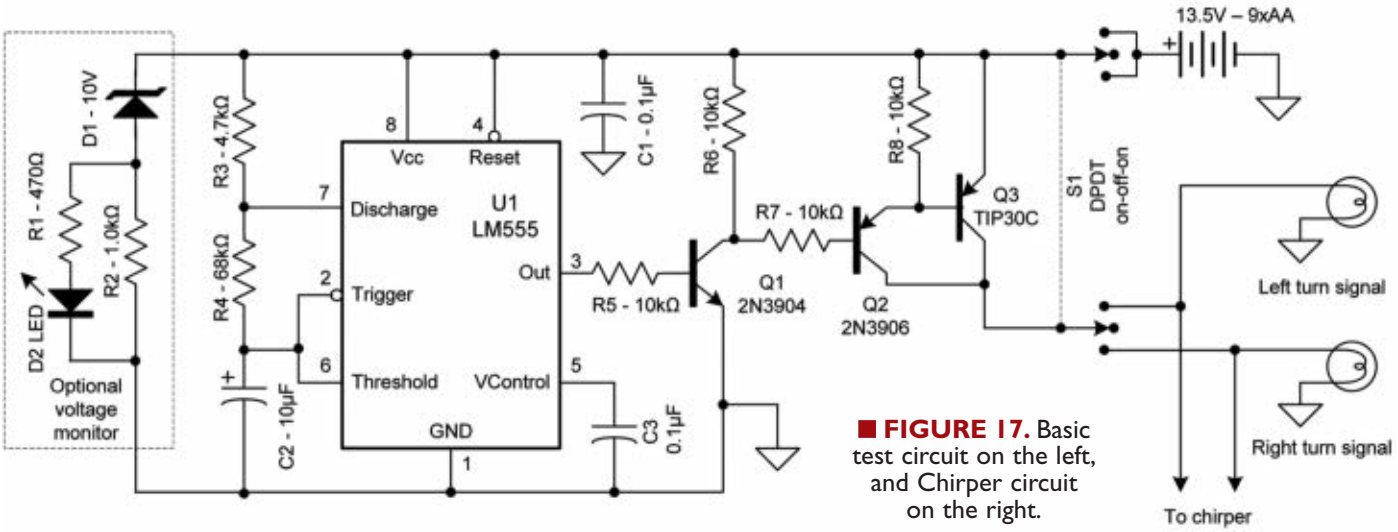
1984 BMW R80RT — Wired it directly to the two rear lights; put it under the seat. Works great.

2012 BMW R1200GS — Wired it to the two front turn signal lights, put it under the dash. Works great.

I used 'mid-line wire taps' (as shown on the demo board in the testing section; see **Figure 13**) to make the electrical connections without altering the original wiring. I used taps from an auto parts store designed for 22-16 AWG wire. Use double-stick tape, Velcro®, wire ties, etc., to securely mount the Chirper; it's very light and won't need much support.

Late-model cars may seem to present installation problems because wiring is so well hidden and may use a system like CANbus. Fortunately, wiring directly to the turn signal lights should work every time.

LEDs. LED turn signal lights may or may not provide as good a ground return as the off incandescent lights do. If you use LEDs for turn signals, you can connect the COM terminal on the Chirper PCB to the frame ground on your vehicle. This will fix the problem; the total impact is that it becomes a three-wire installation instead of two. No other changes are



■ **FIGURE 17.** Basic test circuit on the left, and Chirper circuit on the right.

PARTS LIST FOR THE DEMONSTRATION UNIT

ITEM	VALUE	DESCRIPTION	DIGI-KEY PART #	EA.*	TOTAL*
B1	13.5V battery	Nine (9) AA alkalines	P646-ND	0.35	3.15
Battery holder		Three three-cell holders	2464K-ND	1.77	5.31
D1	10V zener	1N5240	1N5240BVSCT-ND	0.42	0.42
D2		Red LED	754-1218-ND	0.13	0.13
R1	470 Ω	1/4 watt, 5% tolerance leaded resistor	S470QCT-ND	0.08	0.08
R2	1.0 kΩ	1/4 watt, 5% tolerance leaded resistor	S1kQCT-ND	0.08	0.08
R5-R8	10 kΩ	1/4 watt, 5% tolerance leaded resistors	S10KQCT-ND	0.08	0.32
Q1	2N3904	NPN GP transistor	2N3904FS-ND	0.18	0.18
Q2	2N3906	PNP GP transistor	2N3906D26ZCT-ND	0.20	0.20
Q3	TIP30C	PNP power transistor, 1A	TIP30C-ND	0.59	0.59
12V, 6W (500 mA) bulbs and sockets from a hardware store					
Component cost (less lamps and sockets)					$10.46

*Prices at time of printing. Prices may have changed.

necessary. Try testing with the two-wire setup first, though; it may just work. This solution will NOT work with positive-ground cars. (Please don't tell me you've got a vintage Austin-Healey with LED turn signals!)

Of course, myself and *Nuts & Volts* assume no responsibility for any damage to a car or motorcycle from this installation.

Testing

If you're like me, you'll want to fiddle with the circuit and see how it works. Even if you don't have an oscilloscope, much can be learned from breadboarding the Chirper ahead of time and playing with parts values to see the effects. If you have a 'scope, you'll have a ball (and learn a lot). The circuit in **Figure 14** is right out of an LM555 application note, with components chosen for about 1 Hz. The 9V battery supply is handy, but the lower voltage will substantially reduce the Chirper's output volume.

When testing, you'll like the lower sound level anyway; you may want to attenuate the Sonalert further with a bit of tape over its opening. That works pretty well and may save your sanity.

I also built a demo board which is sort of a 'souped up' test fixture. It uses many of the same parts as the basic test fixture.

For the 'demonstration' test set, the voltage monitor can be omitted; then you are left with the basic test circuit plus a big battery (for the 500 mA lamps) and a three-transistor current amplifier to drive the lamps. Another fun exercise. NV

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Compiled Basic for the PIC on a Shoestring

Whether you're a PICAXE aficionado who longs to progress to faster programs or are already a PIC devotee who wants something easier than assembler language to work with, here's just the ticket. In this article, I'll show you how to set up a complete integrated development environment (IDE) for writing, compiling, and burning Basic programs into just about any PIC microcontroller. This is a very slick affair, and the price is sure to please everyone!

By Thomas Henry

If you're new to the world of microcontrollers, then here's the deal. With a system like this, you'll be able to write a program in a language closer to what humans use (that's Basic here), but be able to convert it to something the microcontroller likes (that's machine code). Burning simply means storing the machine language equivalent you've just created inside the microcontroller; this puts the chip through its paces.

At the heart of it all is the Great Cow Basic compiler — perhaps one of the world's best kept secrets. I learned of this fantastic program after Russell Kincaid casually mentioned it in one of his monthly Q & A columns.

As it turns out, the compiler is extensible and extremely versatile, yet absolutely free of charge. It represents the work of Hugh Considine with contributions by others, as well.

Great Cow Basic is essentially a command line compiler; in this form, it's a bit clunky to use, but that's good! Since Great Cow Basic (GC Basic from now on) has such a simple interface, it's a snap to connect it to other programs.

I decided to hook it up to the inexpensive TextPad — a well respected programming editor. While many other text editors could be used, I really think this is the one with the greatest versatility and speed. As you'll see, we'll wind up with a slick IDE which looks and acts just like a system costing hundreds of dollars. You can actually download a free evaluation copy which is completely unfettered, but if you decide to keep using it then you really should pay the paltry $27 asked like I did years ago. I continue to employ TextPad for all manner of programming purposes (C++, C, Basic, assembler, Pascal, HTML, Javascript, Java, batch files), as well as the usual text sort of things like notes, letters, and recipes.

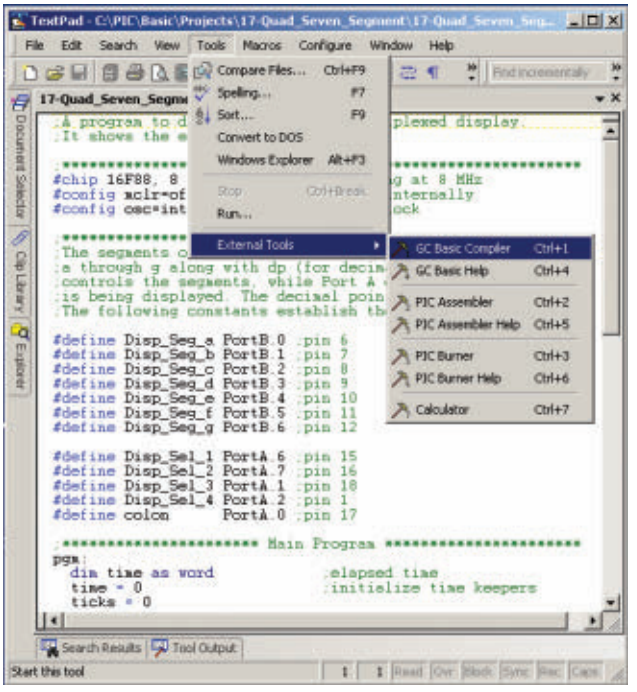

Figure 1: This inexpensive system looks and acts like a commercial IDE.

To whet your appetite, **Figure 1** shows a screenshot of what my IDE looks like now. You'll notice that the pulldown menu has options for compiling, assembling, and burning — all from within TextPad. You might also observe that I've even worked in the Help files for all of these, along with the Windows calculator (handy for changing number bases). But there's more!

If you inspect the source code in the background carefully, you'll see that color syntax highlighting is also present; I'll show you where this comes from, too. Naturally, everything is customizable.

What You'll Need and Where It Goes

To turn this into a full-fledged PIC programming environment, you'll require the following pieces of software:

- TextPad
- Great Cow Basic compiler
- MPASM PIC assembler
- Burning software for your PIC programmer

The first three items can be downloaded from the Web, while the fourth will no doubt come with whatever burner you buy. See the **sidebar** for the appropriate URLs.

Begin by installing TextPad. Next, "install" GC Basic. This is really little more than copying some files over. I stored things in C:\Program Files (x86)\GCBASIC. I recommend spending a few moments rearranging the folders and files somewhat to keep things neat and tidy. **Figure 2** shows how I apportioned things.

The MPASM PIC assembler is also available free of charge directly from Microchip (the manufacturer of PICs). It's part of the MPLAB IDE software, so install that suite next.

I'll leave the burning software up to you since it depends on the programmer you own. Just so you know, I'm using a development board made by Matrix Multimedia and the burner software is called PPP.

Let's put in the color syntax checking files now. You'll find the one I concocted for GC Basic at the article link. You might as well get the one for PIC assembly language, too; look for it at the TextPad website. Store both of these files (they have .syn file extensions) in the TextPad\System folder.

You can pretty much install the TextPad, GC Basic, MPASM, and burning software wherever you want, making any changes to the installation process described below as needed. There is one thing that has to be rather specific, however. MPASM has a nasty quirk of not being able to deal with directory/filename combinations greater than 62 characters long. This means that you'll want to keep all of your personal programming files close to the root of the C: drive just so the fully-qualified file name is short. Again see the screenshot of my arrangement in **Figure 1**.

The root directory is C:\PIC which is short and sweet. Observe, too, that this directory contains two batch files — MPASM.BAT and GCBASIC.BAT — which help TextPad search for errors and position the cursor on any found.

I've provided this entire directory for you, including the batch files and a sample to get you going. Download it from the article link and then copy the entire directory over to your hard drive.

We can now dig into the particulars of how to set up the various requirements. Let's begin with a general Windows thing.

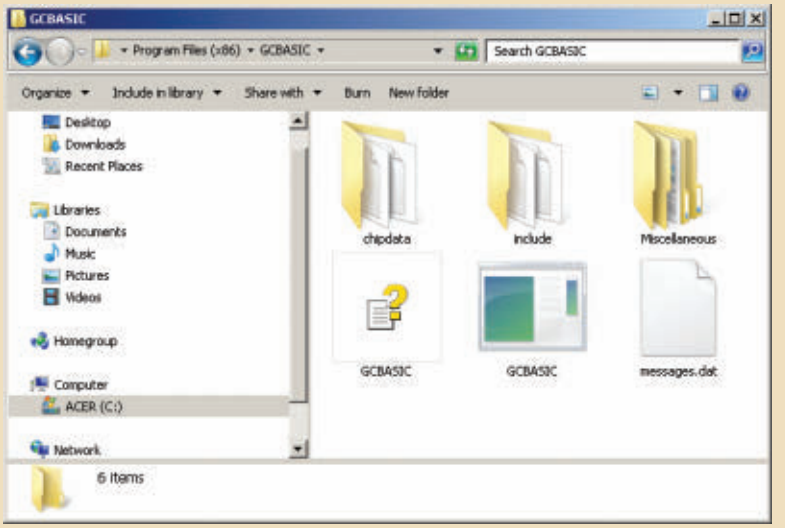

Figure 2: Rearrange and organize the GC Basic files.

You can find the various packages required to set up your custom IDE on the Web. Since software is often updated, I'll mention the version numbers of the programs I use. Really, hooking everything up should be possible both with earlier and later versions.

Program	Author/Manufacturer	Version	URL
TextPad	Helios Software Solutions	5.4.2	**www.textpad.com**
GC Basic	Hugh Considine, et. al.	0.9	**www.gcbasic.sourceforge.net**
MPASM	Microchip Technology, Inc.	8.80	**www.microchip.com**
Batch and syntax files	Thomas Henry	NA	**www.nutsvolts.com**

The instructions detailed in this article show how things look when connecting the software under Windows 7. The steps are similar for Windows XP (in fact, easier). I have run this IDE successfully on several different machines and operating systems.

Finally, the burning software you use is determined by your burner and probably comes with it, which was my case.

How the IDE is Used

To give you a feel for what to expect, here's an overview of how a programming session might go. You begin by creating a Basic source file, and the color syntax highlighting will check your work as you go along. You'll then save this file with a .gcb extension. Next, from the Tools pulldown menu in TextPad, you'll select GC Basic Compiler. This will automatically invoke the compiler and create an assembler source file. A Command Results box reports the outcome. If there are one or more errors, these will be listed along with the offending line numbers. Simply double-click on one of them and the Basic source will be reloaded with the cursor positioned on the naughty line. On the other hand, if everything went smoothly then you'll automatically be back in the Basic source file. Now, invoke the PIC Assembler from the Tools pulldown. TextPad is smart enough to apply the assembler to the assembly code just created (and not the Basic source).

Once again, if there are any errors you can double-click on them in the Command Results window and you'll be taken to the offending line within the assembler file. If everything is hunky-dory, an executable .hex file with the same base name will have been created, and you'll be returned to the Basic source code once more.

Select the PIC Burner from the Tools pulldown. TextPad will then invoke the burning software, and send the hex file along the programming cable. Assuming there were no hardware issues, your PIC is burned and ready to go!

You'll note that with this setup, TextPad automatically applies each tool to the correct type of file. It also keeps your base name intact and appends the correct type of extension as required. You can use long Windows names, but must avoid titles containing spaces — this sometimes confuses the editor, compiler, or assembler. Here are the file types and extensions we'll create for use by the IDE:

.gcb	Great CowBasic source file
.asm	Assembler source file
.err	Error file
.lst	Listing file
.hex	Machine (hex) code file

By associating these file types with TextPad, you can open the files at once by simply double-clicking their icons in any folder view, say, from My Computer or Windows Explorer. You'll note that I've kept the compile/assemble/burn stages separate. My reasoning for this is that after compiling, I like to inspect the generated assembly code first. If it looks good, then I send it to the burner. Of course, if you want, it's easy enough to coerce GC Basic to not only compile, but to assemble and burn all in one fell swoop. A simple batch file is all it takes.

If this sounds interesting, then proceed with the following steps. While none of this is particularly difficult, it is important to follow directions carefully in the correct order, and thus profit from all the hours I spent deciphering how these guys interact. So, slow down, take a deep breath, and keep a pencil and paper nearby.

1. Create a Default Basic File Type

The first step is to get Windows to recognize the GC Basic source as a legitimate file type with its own extension. In these first actions, then, you'll be working within Windows exclusively to set things up. Windows 7 is assumed throughout.

1. Begin by saving a dummy program called "dummy.gcb."
2. Now, from Windows open *Start/Control Panel/Programs/Make a file type always open in a specific program.*
3. Locate the .gcb extension and click the Change Program... button.
4. Press Browse and locate Textpad.exe on your computer.
5. Press OK, and then press Close.
6. Repeat these steps if there are any other file types you think you might need. I like having .lst, .err, .asm, and .hex handy.

2. Make Double-Clicks Intelligent

Now, you'll want to associate GC Basic files with TextPad. This means that when you're looking at a directory and double-click on a GC Basic file, it will automatically open in TextPad.

1. Invoke TextPad and close any open files.
2. Select Configure/New Document Class from the menu bar.
3. Enter the following as the Document Class name: GC Basic Source.
4. Press Next.
5. Enter the following as the default file extension: *.gcb.
6. Press Next.
7. Check the box for Enable Syntax Highlighting.
8. The pulldown list should show the GCBASIC.SYN you installed earlier. Select it.
9. Press Next and then Finish.
10. Select Configure/Preferences from the menu bar.
11. Select Associated Files in the selection tree on the left.
12. Enter the following in the New Extension text box: .gcb.
13. Enter the following in the Description text box: GC Basic Source.
14. Press Add and then OK.
15. Repeat these steps for any other file types you wish to associate with TextPad. I've got mine set up to recognize .gcb, .asm, .err, .lst, and .txt.

3. Include File Filters in TextPad

Next, you'll want to append the *.gcb filter to the file menus. This will make it fast and easy to find and open GC Basic files. In other words, when you invoke a file open or file save operation, you'll be able to specify filters or wildcards in the input box.

1. Select Configure/Preferences from the menu bar.
2. Choose File Name Filters from the selection tree on the left.
3. Press New.
4. Enter the following in the New text box: GC Basic Source (*.gcb).
5. Enter the following in the Wild Cards text box: *.gcb.
6. Use Move Up or Move Down to position your filters as desired in the drop-down list.
7. Press OK.
8. Repeat this for any other filters you may want; *.asm and .lst would be useful.

4. Adding the Compiler, Assembler, and Burner Tools

The time has come to connect TextPad with GC Basic for a truly integrated system. Pay very strict attention to every character, digit, and punctuation mark as you set things up here. You'll also want to double-check any directory or folders that might be different on your system from mine.

1. Select Configure/Preferences from the menu bar.
2. Select Tools from the selection tree on the left.
3. Press Add and then Program.
4. Browse to your GC Basic.bat file and press Open.
5. Press Apply and then OK.
6. Rename the listing to GC Basic Compiler and press OK.
7. Again, select Configure/Preferences from the menu bar.
8. Expand the Tools branch in the selection tree and then select GC Basic Compiler.
9. Fill in the box according to the screenshot in **Figure 3**. Most entries will be defaults. Obviously, change anything that applies specifically to your system that might be different from mine.

You will follow similar steps to add the assembler tool. In this case, TextPad will invoke the MPASM.BAT batch file mentioned earlier. Remember, I've included this file in the article downloads for your convenience. The entry box for this in TextPad is shown in **Figure 4**. Next, install a tool to bring up the burner. Naturally, this will be specific to whatever hardware you're using. Just so you can anticipate the sort of thing you'll be doing, there's a screenshot of my system in **Figure 5**.

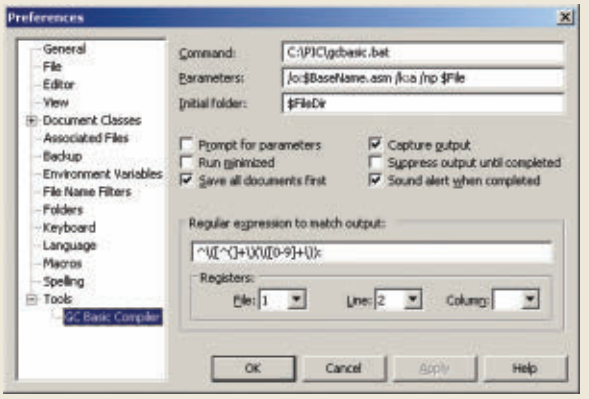

Figure 3: The tool entry box for the compiler.

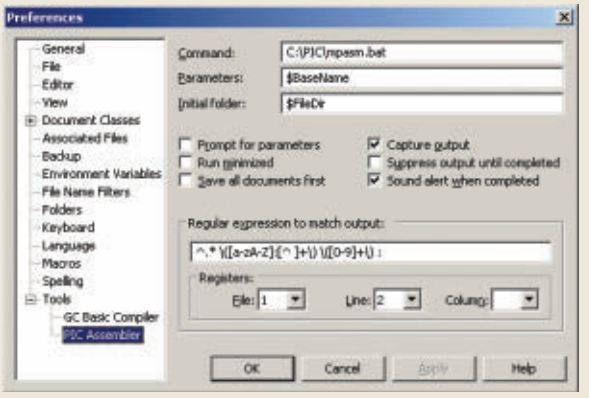

Figure 4: The tool entry box for the assembler.

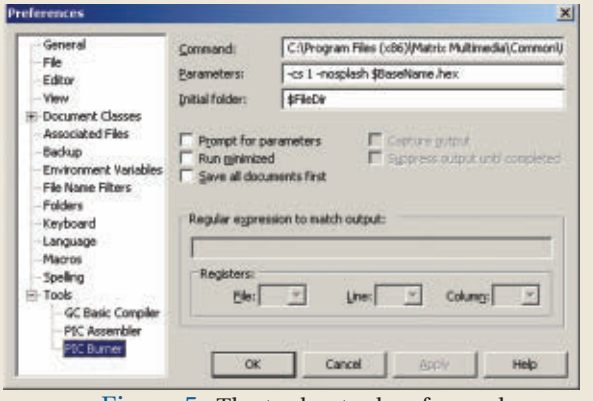

Figure 5: The tool entry box for my burner. Yours may differ somewhat.

5. Engage the Color Highlighting and Other Aids

We've got one final task to take care of before GC Basic is totally integrated. In particular, the color business for the syntax checking needs to be turned on. Keep in mind that you can always come back to this later if you change your mind about anything. As a good start, you might try green for comments, blue for keywords, red for directives, and black for all else. Here's how to set things up.

1. Again, while in TextPad close any open files.
2. Select Configure/Preferences from the menu bar.
3. Expand Document Classes in the selection tree on the left.
4. Expand GC Basic Source in the selection tree.
5. Choose Colors.
6. Set the colors you wish for directives, comments, keywords, etc.
7. Set any other desired features for GC Basic Source code at this time.
8. Press OK.

A Few More Niceties

Since the designers of GC Basic have already created and included a Help utility in their package, a nice touch is to make it readily available in the TextPad toolbar. Here's how to do that.

1. Select Configure/Preferences from the menu bar.
2. Choose Tools from the selection tree on the left.
3. Press Add and then Online Help File.
4. Navigate to the help file (it has a file extension of .chm) in the GC Basic folder and select it. Press OK.
5. Rename the menu entry to GC Basic Help.

I also added tools to invoke Help for the assembler and burner. Help for the assembler comes with MPASM (part of the MPLAB package), and my PPP burning software also had a compiled Windows help file.

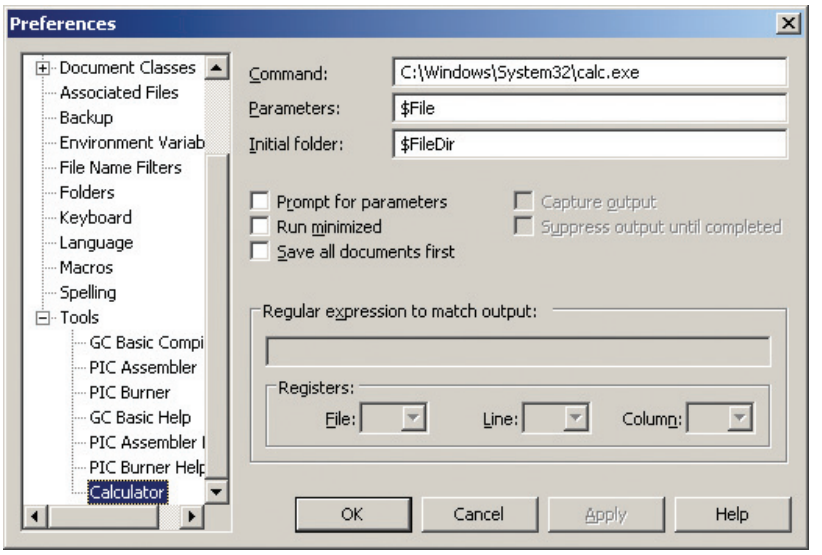

Figure 6: The tool entry box for the Windows calculator.

Finally, it would be handy to add the Windows tool Calculator which is great for working up number base conversions and so forth. This useful accessory comes with Windows, so again your investment in the system is minimal! I found it located in the Windows\System32 subdirectory. **Figure 6** shows what the installation in TextPad looks like.

That ought to get you going with your new all-in-one Basic compiler IDE for the PIC. Yes, it took a couple hours of work, but can you believe such a system is possible for less than $30? BTW ... GC Basic can also be used with most AVR microcontrollers. **NV**

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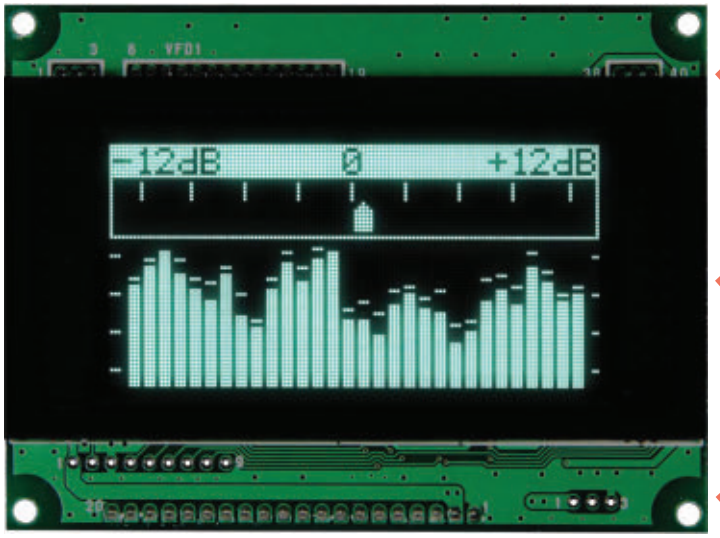

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■ BY JOE PARDUE

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Part 4 FRITZING WITH THE ARDUINO

Last month, we continued learning about Fritzing — a novice-friendly electronics hardware design package — useful for things like designing shields for an Arduino. We got better acquainted with Fritzing features and learned how to create some parts. This month, we'll go deeper into making parts with Fritzing.

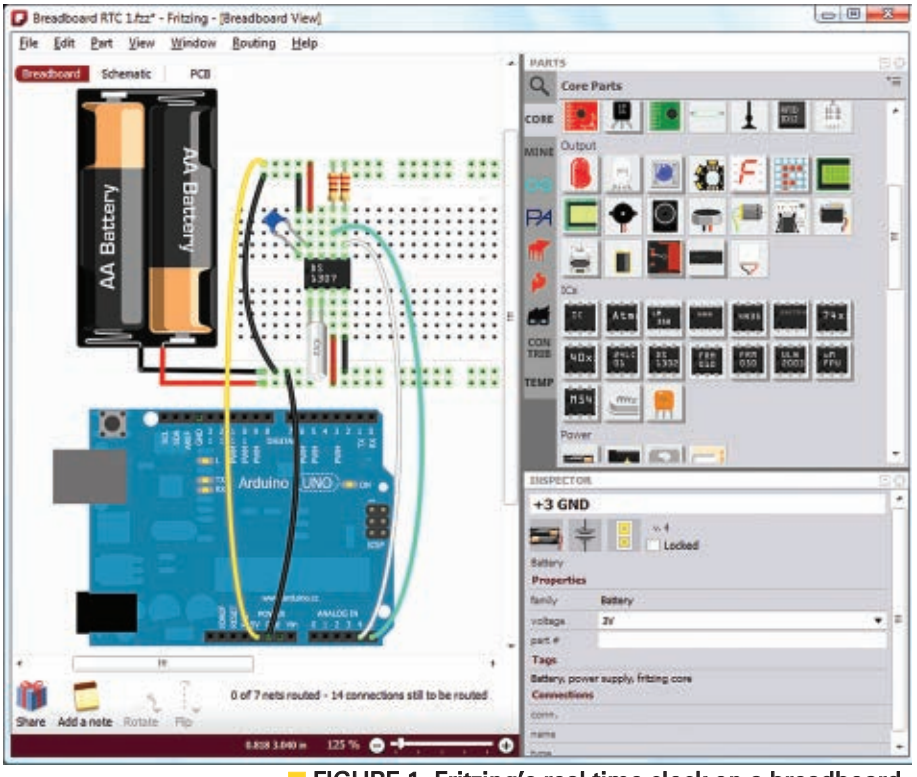

FIGURE 1. Fritzing's real time clock on a breadboard.

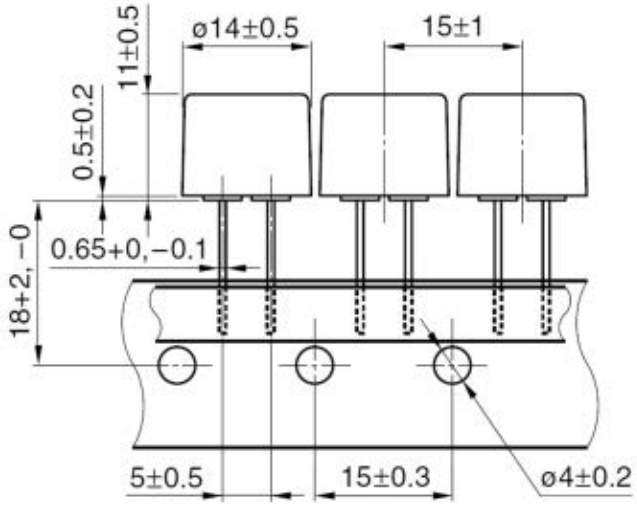

FIGURE 2. Piezo shape and dimension.

LET'S CREATE A NEW PIEZO SPEAKER PART

A piezo speaker is a useful part since it allows us to have audio feedback using only a single Arduino pin. We will create a part for a piezo speaker described in the datasheet found at **www.tdk.co.jp/tefe02/ef532_ps.pdf**. You can get this part from Mouser by searching for PS1420P02CT.

We don't really need the datasheet for the electrical characteristics since the Mouser page tells us it is a 5V device and we will be running it with 5V pulses. We do need the dimensions of the part for drawing it, though. We find the shape and dimension illustration in **Figure 2**.

This also includes the paper tape for the devices that come on reels for automatic insertion during manufacture, but we only need the dimensions for a single device.

FIGURE 3. The piezos.

Figure 3 shows a photo of the devices on the tape; this will help to make our part look more like the original. We see that it is 14 mm in diameter, and the legs are 5 mm apart and 18 mm long.

Since they have such relatively long legs, we could either plug them directly into a breadboard or we could bend the legs parallel with the bottom and then extend 11 mm over the edge (14 diameter/2 give the radius of 7 which we subtract from the leg length of 18, giving 11 mm).

We can then bend the legs down as shown in **Figure 4**, thus allowing the piezo to be used on a breadboard without covering holes unnecessarily (as shown in **Figure 5**). Since we will be bending these legs like this, let's draw the part as showing the legs coming out the side so that it will appear in Fritzing the same as on the real breadboard.

FIGURE 4. Piezos with legs bent.

FIGURE 5. Piezo on a breadboard.

Last month, I discussed why I chose Inkscape to produce the .svg (scaled vector format) for use with Fritzing. The main reason is that it's free, and as these kinds of programs go it is not too hard to use. However, I also mentioned that I keep Google open and have to search on almost every command I use. We won't discuss how to use Inkscape here but I may provide a few hints for things that help with Fritzing.

The first thing you'll want to do is open the View menu and select Grid. You'll see a grid appear. Next, open the File\Document Properties window and under the Page tab, change the Default units from px to mm and the Custom Size units from px to mm. Under the Grids tab, change Grid units from px to mm. Now, you'll be able to draw a circle for the piezo using mm — the dimension we know — and not px (which we'd have to guess at).

To draw that circle, click on the Create Circles, Eclipses, and Arcs icon in the tool bar on the left edge of Inkscape. Draw a circle and click the black color bar on the bottom of Inkscape to generate your base drawing. Next, click the Arrow icon at the top of the left tool bar and you'll see on the upper toolbar that you have some dimensions to mess with. Click the lock icon to Lock the X and Y dimensions, then enter 14.

Now, you have a 14 mm black circle. If you refer to the **photo**, you'll note that the top view of our piezo element has a hole in it and that hole looks a lot blacker than the surrounding area. Okay, so let's change our base circle to dark gray, then use the same method we used before to create a black circle in the middle.

Use the Fill and Stroke window to set the color of the bounding circle to a lighter gray than the base circle. Use the X and Y boxes to get it centered, and then use the Arrow to draw a box around them.

Next, click the Object menu and Group so that now these two circles travel as a unit. You should have something that looks like **Figure 6**.

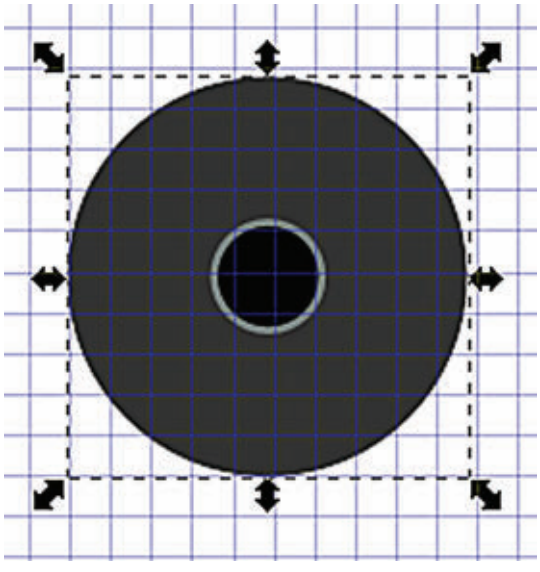

FIGURE 6. Drawing circles.

Next, we want to add the legs that stick out to the side and are bent down. Of course, we'll only see the top view but these are the legs that we'll add the connection point in Fritzing to.

Go back to the Document Properties and set the Grid units to 'in' and the Spacing X and Y both to 0.1, so we can set the legs to 0.1" centers to match a breadboard. Also, let's start this up a little with a couple of 'reflections.'

We use the Draw Freehand Lines tool to draw two lines as shown in **Figure 7**. (Set the color to white and the rounded ends in the Fill and Stroke window.) Finally — **and this is very important** — before saving the .svg file, you must make sure you do two things to be compatible with Fritzing. First, in the Documents Properties window under the Page tab under Custom Size, click to "Resize page to drawing or selection;" then, under the File menu use Save As and save the file as a plain svg file. *Do not save it as an Inkscape svg file!* The final drawing is shown in **Figure 7**.

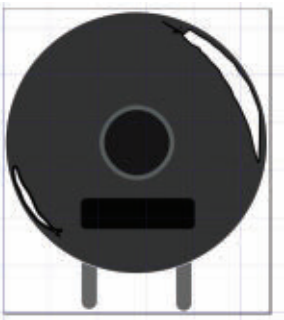

FIGURE 7. Piezo SVG drawing.

USING THE FRITZING PARTS EDITOR

The Fritzing Parts Editor is not quite ready for prime time as of this writing. For simple parts, it's great, but I had fits trying to do some more complex parts. The guys at Fritzing are actually completely open about this as you can see in **Figure 8**; you get warned when you open the Parts Editor. They (well, Jonathan Cohen) were very helpful and Jonathan is frank that if you want to do anything beyond simple, you'll probably need to learn how to edit the Fritzing XML files. This is something we do not want to do. Since this part is very simple with only two pins, we can do it without much worry.

Open the Fritzing Parts Editor shown in **Figure 9**. The editor shown in **Figure 10** is used to create a part with four images required for it. These are: the icon, which is a small version of the part that shows in the Parts window; the breadboard image that will show on the breadboard; the schematic symbol that will appear in the schematic drawing; and the PCB symbol that will appear in the PCB drawing. We will use our piezo svg drawing for both the icon and the breadboard part, and we will reuse symbols from the Fritzing directory for the schematic and the PCB symbols.

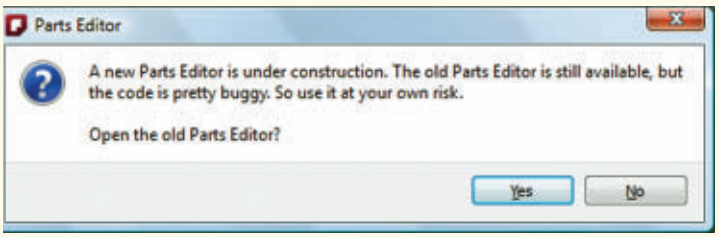

FIGURE 8. Parts Editor under construction.

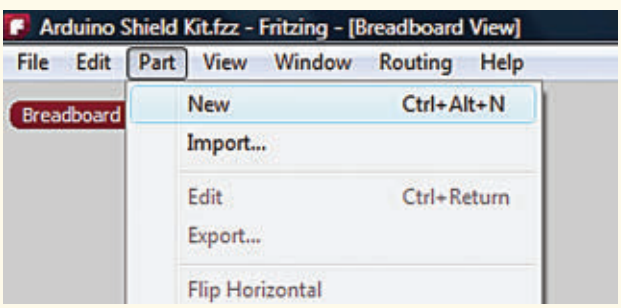

FIGURE 9. Designing a new part.

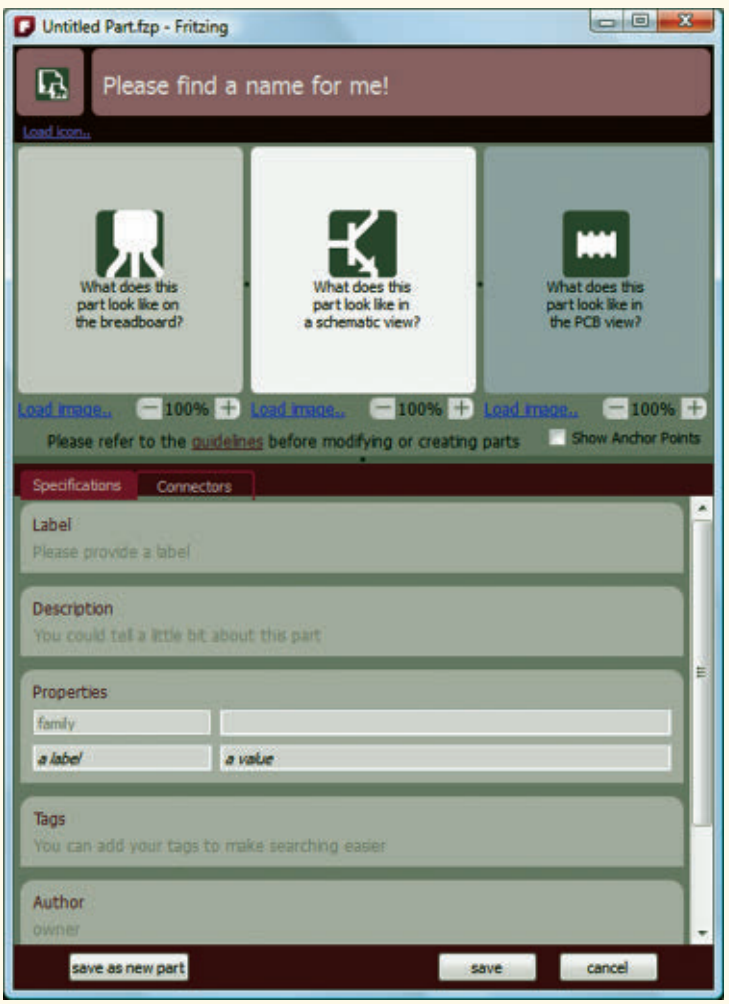

FIGURE 10. Fritzing's Parts Editor.

First, let's name our part Piezo Buzzer to differentiate it from the existing Fritzing core part 'Piezo Speaker.' At the top of the Editor, click on 'Please find a name for me' shown in **Figure 11**, then fill in the name and click Accept. The results are shown in **Figure 12**.

Next, click on the 'Load icon' link at the top, and browse to find the piezo.svg file. Click on that, and you'll now see your piezo image as shown in **Figure 13**.

FIGURE 11. Enter a name.

FIGURE 12. Name accepted.

FIGURE 13. Icon loaded.

FIGURE 14. Breadboard image loaded.

Next, click on the 'Load image' link and browse to the same image; select it and you'll see what's shown in **Figure 14.** This shows something neat about vector graphics like our .svg file. It is scalable, so the image can be shown smaller or larger, and in the breadboard image window. In a moment, we'll see how easy it is to enlarge the image that will help us attach the pin connections. This feature is very helpful as we create the documentation for our projects. We can easily generate a 72 dpi (dot per inch) image for showing in a web browser, or we can generate a 300 dpi (or larger) image when we want to print it to paper.

Now, we want to get the schematic and PCB images. Go to your Fritzing directory and open the parts\svg\core\schematic directory and find loudspeaker.svg. Now, click the Load image link under the schematic window and select that file as shown in **Figure 15**.

For the PCB image, we need to remember that the pins are 5 mm apart and there are 2.54 mm in 0.1 inches, so we want two holes that are 0.2 inches apart. It just happens that under the PCB directory, we have Buzzer-v15_pcb.svg, so let's select that and see if it is the right size.

Well darn. It is too big and the

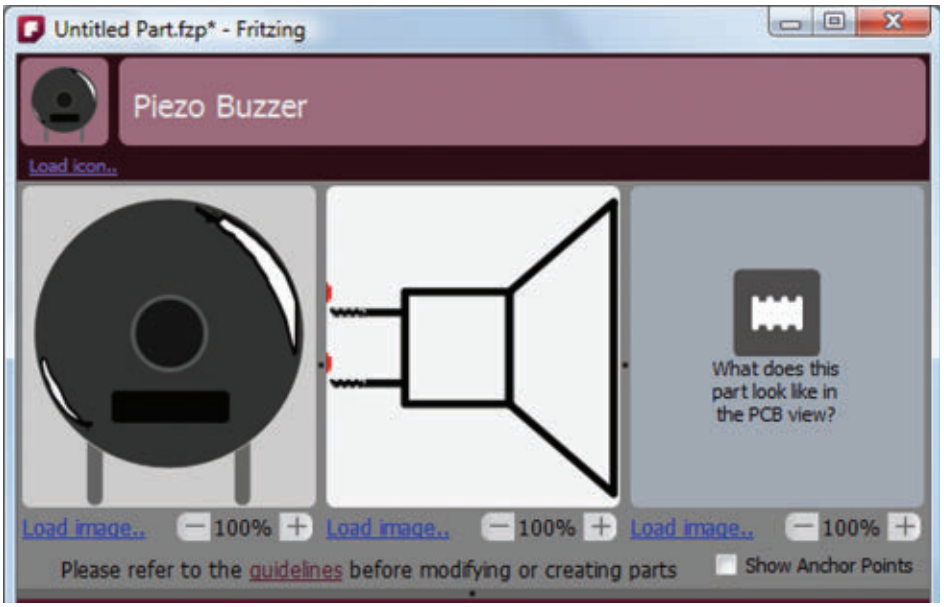

FIGURE 15. Schematic image loaded.

holes are too far apart. Good thing we can save some trouble by opening it in Inkscape and adjusting things to fit our needs. We can then save it as Piezo_PCB.svg and import that into the Parts Editor as shown in **Figure 16**.

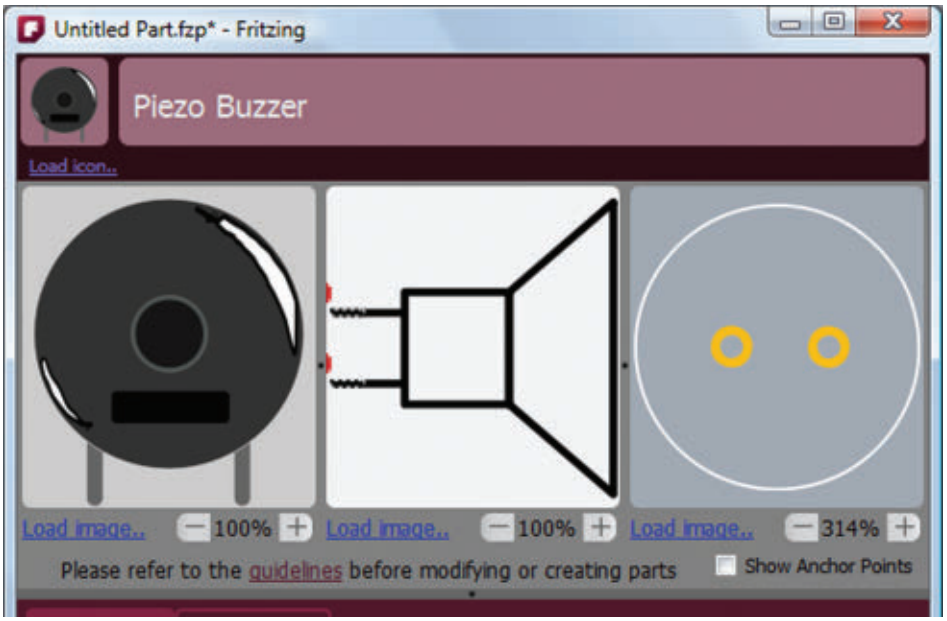

FIGURE 16. PCB image loaded.

Fill Out the Part Information

You don't have to fill out all the information in the Specifications tab. I set the label to Piezo_buzzer; the description to 'Piezo buzzer PS1420P02CT;' and the author to me.

Making the Connections

If you click on the schematic drawing and roll your mouse wheel, you can change the size of the image. As you can see in **Figure 17**, you've got two red Xs. This indicates that there are connections in the drawing, but they're not synched with the rest of the drawings. Click on the Connectors tab and you see four connections listed as mismatched. Just click the x on the far right and get rid of them.

Click the Add Connector button twice to add two connections. Click the gender icon on the left and select the female symbol, then name each pin as shown in **Figure 18**.

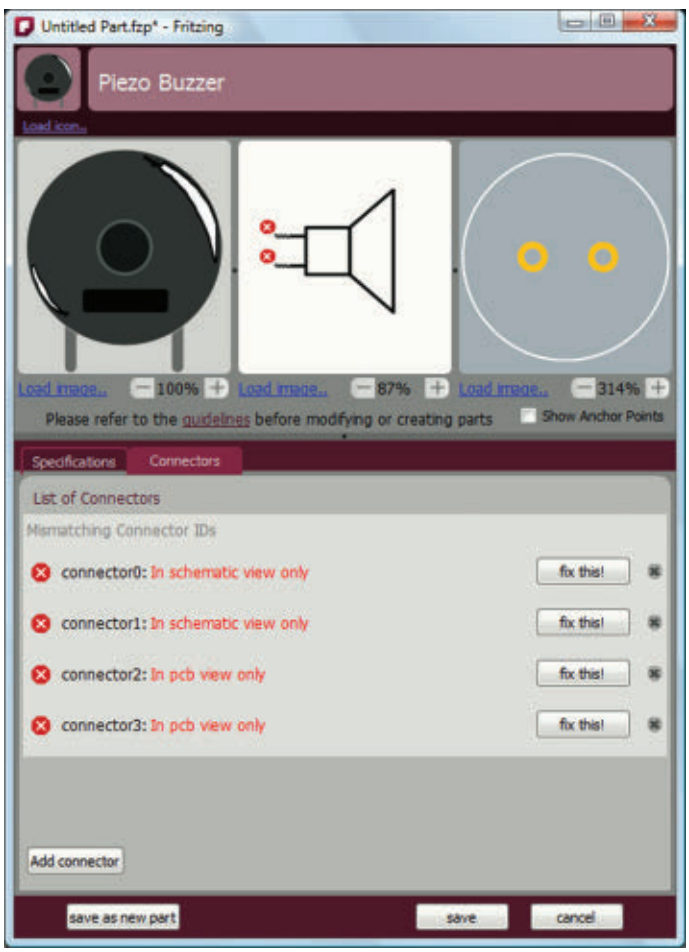

FIGURE 17. Open Connections tab.

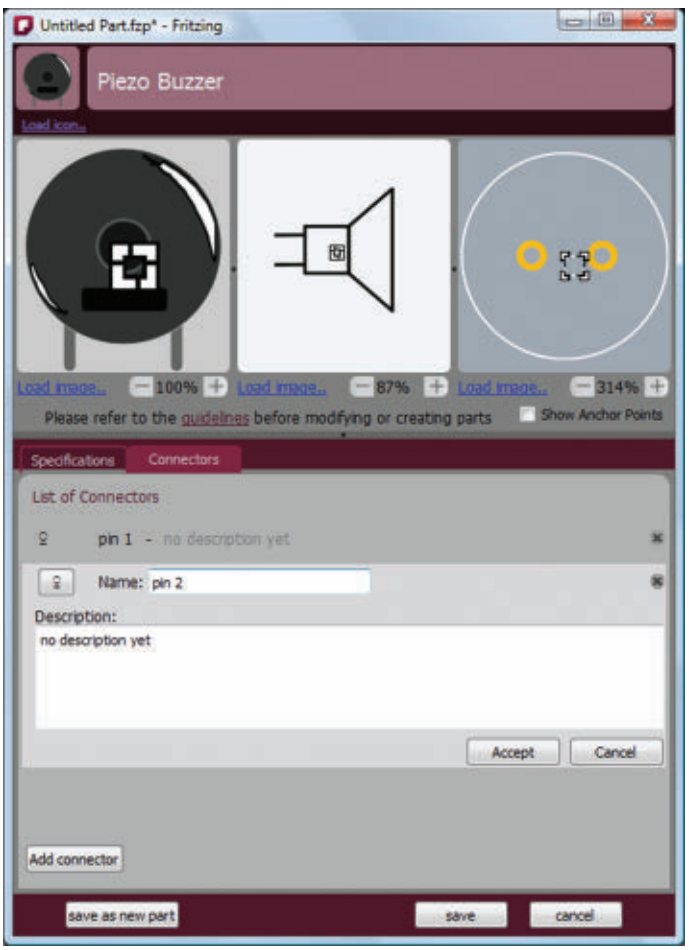

FIGURE 18. Connectors named.

Notice that in each of the images, you see a little white square. This is the connection box and you can select between them by clicking on the list of connectors. It can be very tricky to move these things around and resize them, so you might need to play with this for a while. Select the connector you don't want to move, and then click on the one you do want to move in the image (yes, weird). Also notice that by holding down the shift, the ctrl, or the alt keys while rolling your mouse wheel makes the image move up and down, left and right, or larger and smaller. Take some time to get these connectors placed properly (as shown in **Figure 19**) because this is what Fritzing uses to locate wires. If you get them located wacky, your wiring will look wacky.

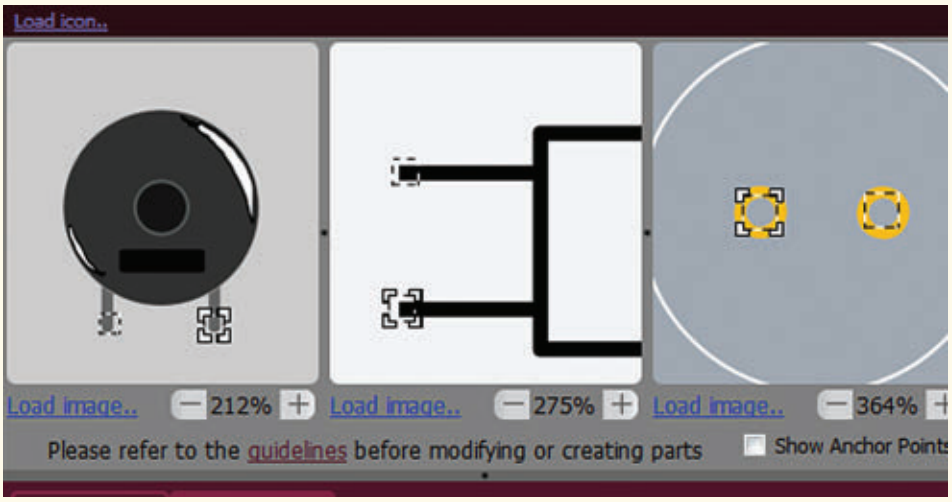

FIGURE 19. Placing the connector.

NOW SAVE IT!

It should appear in the parts bin labeled "MINE" as shown in **Figure 20** (minus the other two icons which are a couple of parts I had in my "MINE" bin at the time).

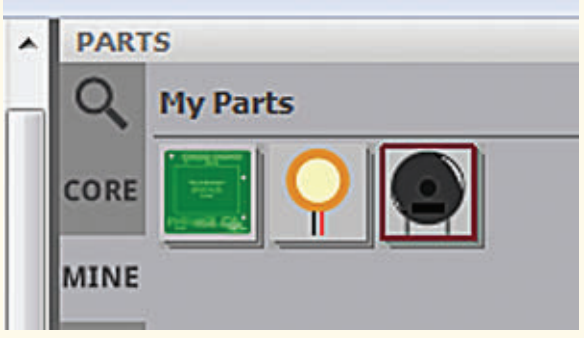

FIGURE 20. "MINE" parts bin.

Using the Ruler

While we were very careful with our measurements when making this part in Inkscape, there are many things that can go wrong. So let's measure the part in Fritzing and see if it is the size we assume it is. The datasheet said the part was 14 mm in diameter, and we added the connectors with 0.2" separation to match the 0.1" spacing on the breadboard. You can find the ruler in the Core parts bin at the bottom. Drag it out onto the Breadboard work area.

Notice that when we grab the buzzer with our mouse that a box appears around it as shown in **Figure 21**. This box is the same as the page size in Inkscape and it is the reason that we resized the page to fit the part before saving it. When we move the buzzer to the ruler as shown, it is 14 mm as we expected.

As a final check, we move the buzzer down to the 1/10" rule and see that the connectors are 0.2" apart as we thought (as shown in **Figure 22**). It might seem like a waste of time to re-measure the part after we've created it in Inkscape, but early on I made some mistakes and made some parts that didn't have the dimensions I thought. So, now I double-check.

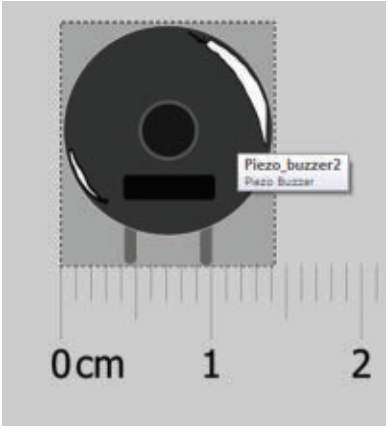

FIGURE 21. Ruler showing our 14 mm buzzer.

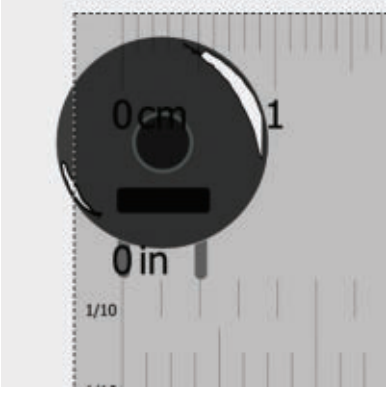

FIGURE 22. Ruler confirming the buzzer connector spacing.

LET'S USE IT

Let's add a piezo to our RTC project so we can use this design as an alarm clock. Open the Breadboard RTC Fritzing file we did in last month's Workshop. You can use the part you created above, or if you want to save some time you can use the part I created (Piezo_Buzzer.fzpz at **www.smileymicros.com**; under the download menu, click the Smiley's Workshop Source Code item).

In Fritzing, click on the Part menu item and select Import (to import the part). It will appear in the Contributed Parts bin; you can drag it to the PCB and wire it up as shown in **Figure 23**. You can then wire the schematic and PCB as shown in **Figures 24** and **25**.

We won't bother to have this board fabricated since it's a learning exercise.

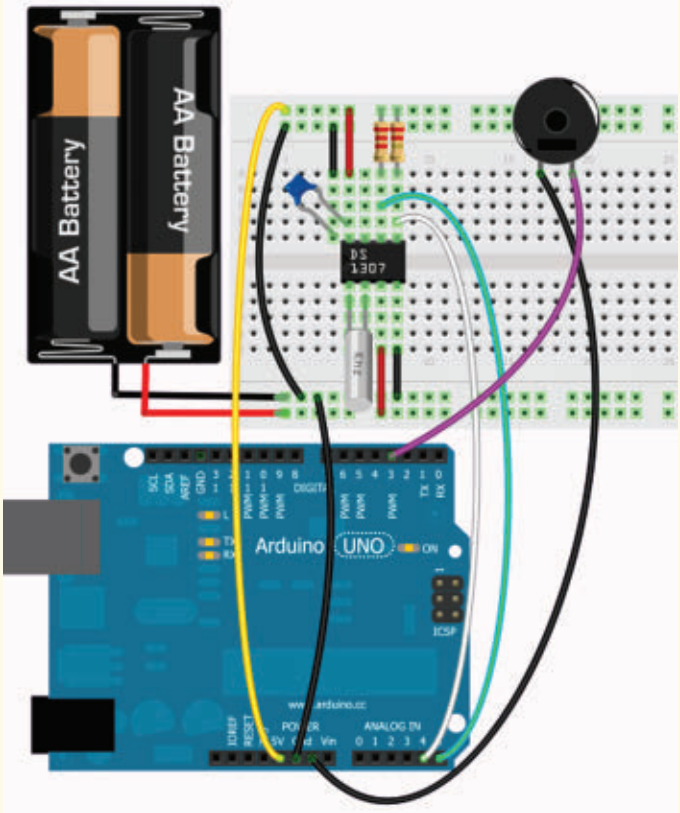

FIGURE 23. Buzzer on an RTC breadboard.

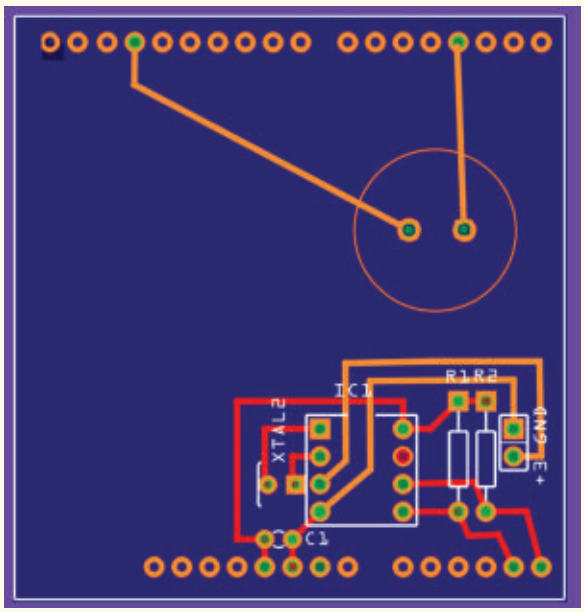

FIGURE 25. Buzzer on an RTC PCB.

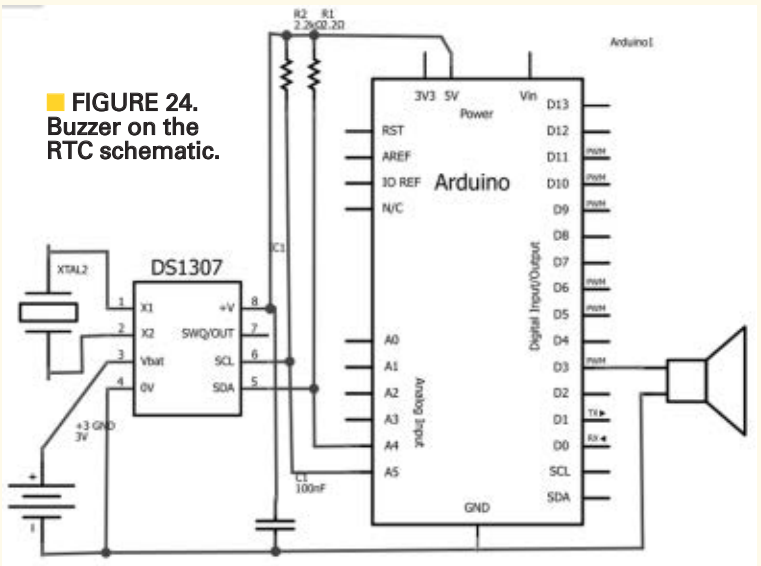

FIGURE 24. Buzzer on the RTC schematic.

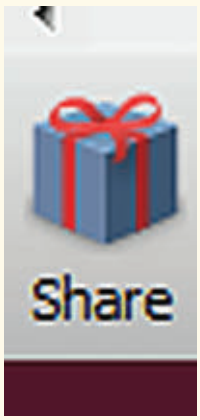

FIGURE 26. Sharing projects.

Sharing Parts

You can share your part by highlighting it, then from the Part menu, click export and save it to a .fzpz file that others can import if they want to use it.

Sharing Projects

After you complete a project, you can share it with the Fritzing community by clicking the 'Share' icon at the bottom of the IDE as shown in **Figure 26**. This will take you to the Fritzing website where you can fill out some forms and share your design — a way to give back to the community.

FRITZING EXAMPLE PROJECTS

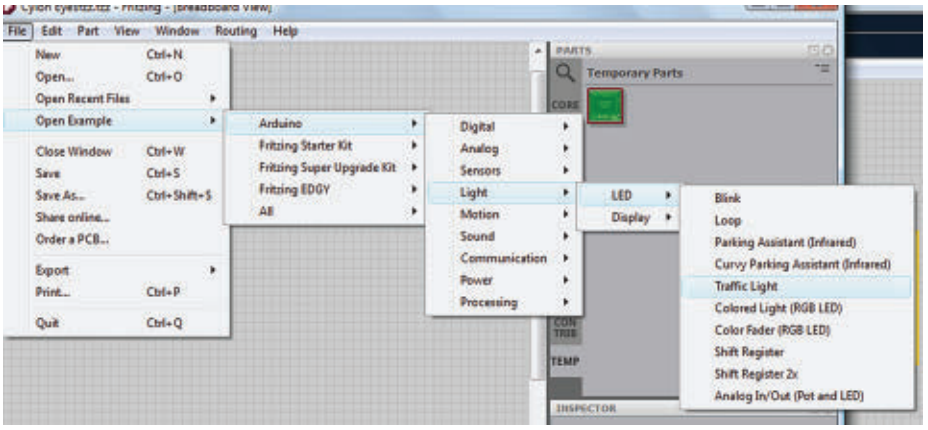

FIGURE 27. Open example for a traffic light.

DONATE TO FRITZING

Another way to give back to the community is to give them some money (**Figure 30**). Open the Help menu and click on the 'Donate to Fritzing' button, then make a donation. Why? Because the only way this great product can get greater is if it gets support from the folks that use it.

I realize nobody has enough money and everybody wants all they can get for free, but I think you should take it as a moral stance that if you are going to use a tool like this, you should throw a few bucks their way to help them out. It is the reason I buy Arduinos.

Of course, nothing forces you to do this, but if you really want to be a member of this growing open source community, you should feel obligated to help out where you can. Sermon over.

Fritzing also has a web shop and sells kits and PCB fabrication services. These are located in Germany and might be more economical for our European friends, but buying stuff from them is also a way to help out.

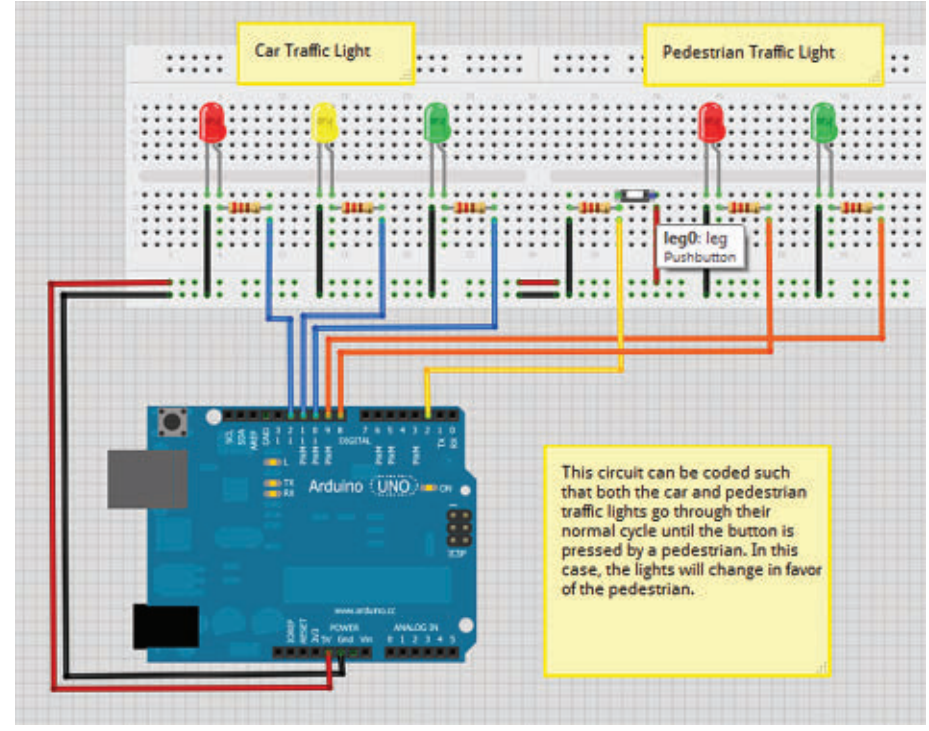

FIGURE 28. Traffic light breadboard example.

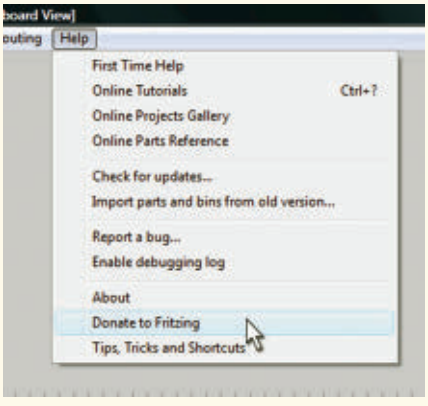

FIGURE 30. Donate to Fritzing.

THE ARDUINO PROTO SHIELD KIT

Next month, we'll create the Arduino Proto Shield that uses a mini breadboard to allow quick and easy prototyping. The available kit is shown in **Figure A**.

You can get a head start on using this board by purchasing it from the *Nuts & Volts* webstore. **Figure B** shows a Fritzing illustration of the Proto Shield with an alarm clock prototyped on the breadboard.

Questions? *Nuts & Volts* is hosting forums for its writers and you can find mine at **http://forum.servomagazine.com**.

If you want a quicker response

Like most software tools, one of the best ways to learn to use it is by looking at other people's example projects. While you can find many on the Internet with a simple search, the Fritzing installation has a bunch of examples included with it that have at least been looked at by someone at Fritzing and judged good enough to include in the distribution.

Open the File menu and then click on the Open Examples item where you will see a list of categories. Click on the Arduino, then expand it as shown in **Figure 27**; you'll get to the Arduino Traffic Light example.

This will display the traffic light example as shown in **Figure 28**.

You can get the software and additional information from Fritzing at **http://fritzing.org/projects/digital-inputoutput-traffic-light** as shown in **Figure 29**. Happy hunting! **NV**

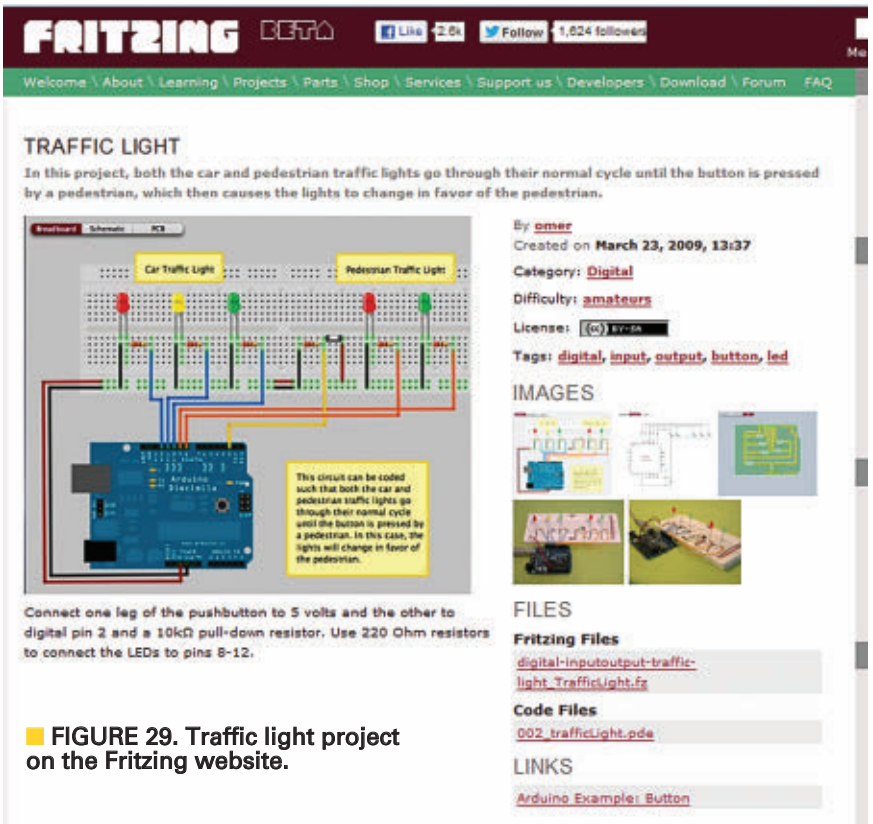

FIGURE 29. Traffic light project on the Fritzing website.

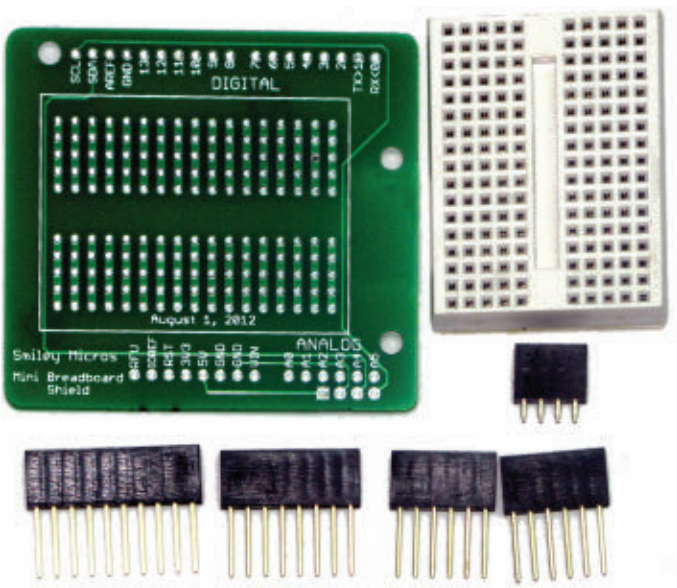

FIGURE A. Proto Shield kit.

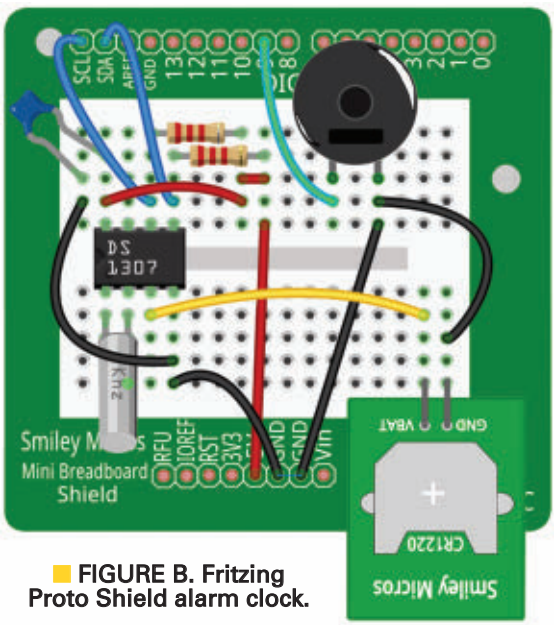

FIGURE B. Fritzing Proto Shield alarm clock.

— especially to a question not directly related to an article — you can put on your biohazard suit and start a thread on **www.avrfreaks.net**.

If you just can't wait and want to get a leg up on all this AVR microcontroller stuff (while helping support your favorite magazine and technical writer), then buy my *C Programming* book, or the *Arduino Workshop* book, or the *Virtual Serial Port Cookbook* — each with projects and a kit of parts to support the text using the *Nuts & Volts Magazine* or their web shop. Go there. Buy something.

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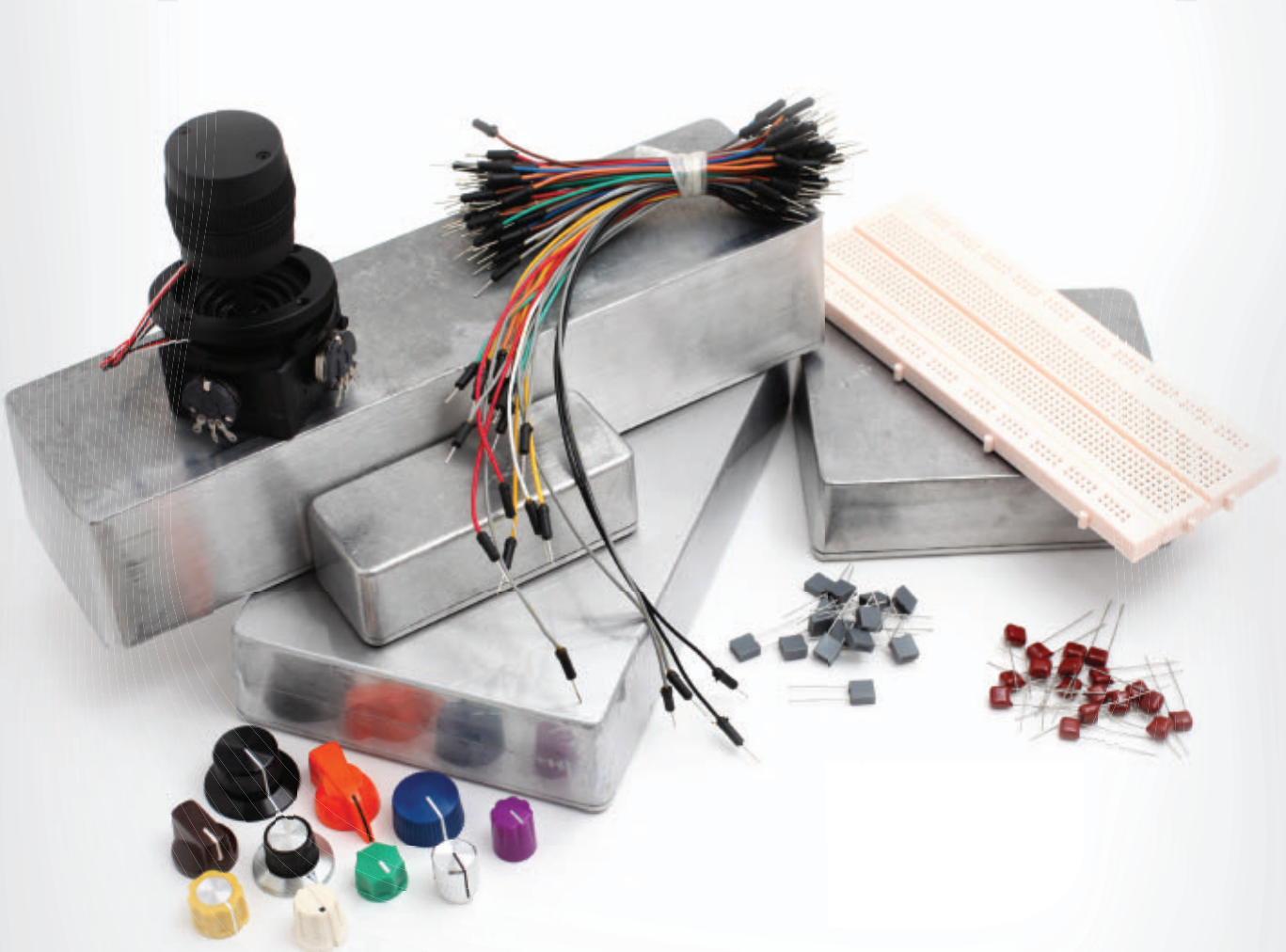

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SPIN ZONE

■ BY JON WILLIAMS

ADVENTURES IN PROPELLER PROGRAMMING

LET THERE BE COLORFUL LIGHTS!

It wouldn't be an end-of-year (well, my end-of-year) column without a discussion on lighting, would it? I really enjoy animated lighting control and the Propeller is an excellent platform for it. This month, I'm going to show you how to use the Propeller to control RGB LEDs with an interesting little driver chip called the WS2801.

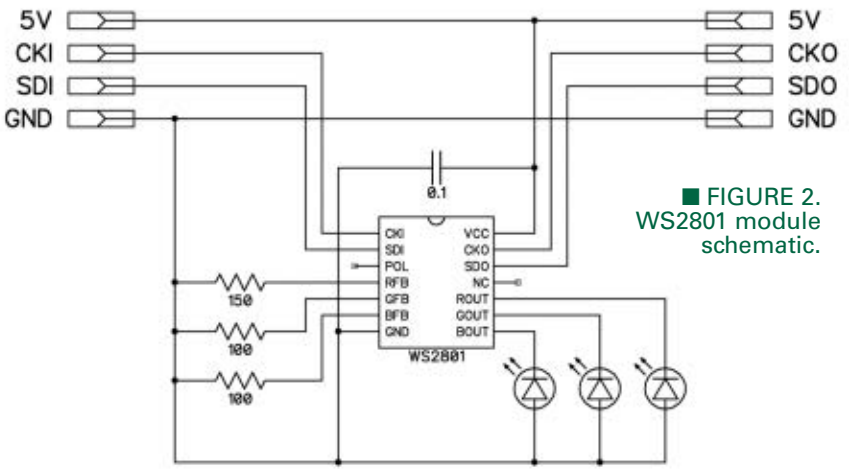
■ FIGURE 1. Ryze from League of Legends.

The past three summers, I have had the really good fortune to get a call from my friend, Steve Wang, to provide electronics help for his team at Biomorphs. Even if you don't know who Steve is, you've probably seen his work in the movies. An incredibly gifted sculptor and painter, Steve rose to prominence in the Hollywood FX community for his wonderful painting of the original Predator character. This was just the start of his amazing career as a quick look at Steve's IMDb page amply illustrates.

While I'm not much of a gamer, I have tremendous respect for the production process of the modern gaming industry because so much of it is borrowed from the way the movie industry produces a film. The same 3D tools used to create movie effects are used to create the characters and environments in today's games. So, how does the gaming industry relate to Steve and ultimately to me? The gaming industry is very big, and like other industries is always looking to attract new customers. A natural part of the marketing process is trade shows. A trade show means a display, and for really cool "Hollywood" quality displays (i.e., something that looks as good up close as it does from a distance), key players in the industry turn to Steve Wang and Biomorphs. I will repeat what I have said many times: Steve has a massively talented team of sculptors, fabricators, mold-makers, painters, and wardrobe people. Where do I fit? When they need me, I fabricate circuits and "paint" with embedded software. Yep, they may just be "blinky lights," but the blinky lights we put into these displays kick some serious backside.

Every year the stakes are raised, and this year was no different. The client — Riot Games — contracted Biomorphs to build a couple characters from their massively-popular online game, League of Legends. LoL

uses very stylized characters (**Figure 1**) in the game and Riot wanted the display characters to look a little more like something out of a movie. This meant that Steve's team had to start from the ground up — there were no 3D models that could be printed and "body shopped;" both characters were sculpted and built from scratch. With experience from previous gaming-related projects (Starcraft 2 for Blizzard and FireFall for Red-5 Studios), I had some code that I could use as a starting point. That said, every project has at least one element that presents a new — often significant — challenge, and this project was no exception.



■ FIGURE 2. WS2801 module schematic.

In this case, it was the character called Ryze who carries a "spell globe" in his hand that looks like a luminous sphere of energy. Now, I must confess to not having played the game but I have seen video of it and this globe seems to be some sort of weapon that Ryze hurls at opponents. Here's the thing: It's pretty easy to create a spell globe as a 3D effect for a video game; it's not so easy to make what we call a "practical" effect (something you can see and touch). The challenge was somewhat akin to creating artificial lightning without the use of high voltages.

After rejecting the use of a store-bought plasma ball, we looked into using LEDs but were not sure if we could pull this off without having to design custom PCBs (the schedule was very tight). After a lot of discussion, Mike Deak — a veteran of blockbuster Hollywood special effects — asked the obvious question: *Is there an LED strip with onboard electronics that would allow control over each element?*

I didn't know at the time, but I did know someone who would have that information. I immediately picked up the phone and called Corey Minion of Minion's Web. Corey is an expert on LEDs and provides them in a wide variety of products. He told me that he had an RGB strip that used the WS2801 controller for each LED. After looking over the specs, Mike ordered a five meter roll and I jumped on the code.

Figure 2 is the schematic for a typical RGB LED application where several modules will be daisy-chained (for single modules, the feedback resistors will be smaller to allow for more current). As you can see, 5V and ground are bussed straight through, while the data and clock signals actually pass through the WS2801 (that will be explained below). The configuration shown is for constant current; note that each output has a feedback resistor for setting current. The formula for calculating the feedback resistor size is:

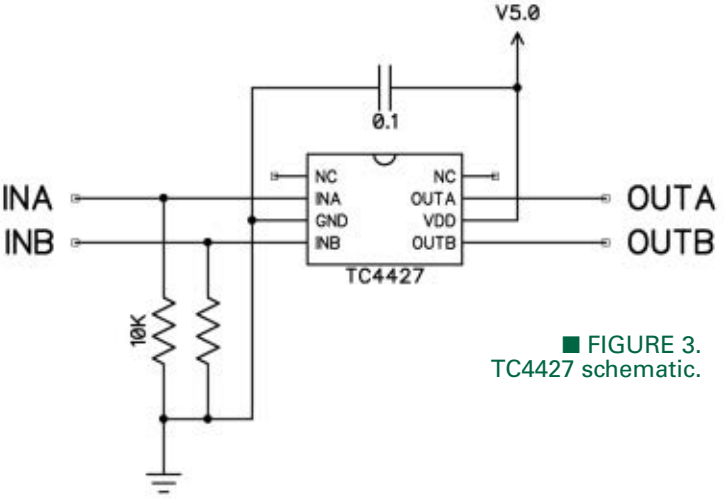
$$R_{FB} = 0.6v / I_{LED}$$

If you want to play with the WS2801 but don't want to build a single circuit, SparkFun offers a neat little breakout board with everything in place. You simply connect power and signals. They also offer a one meter strip with 32 RGB circuits.

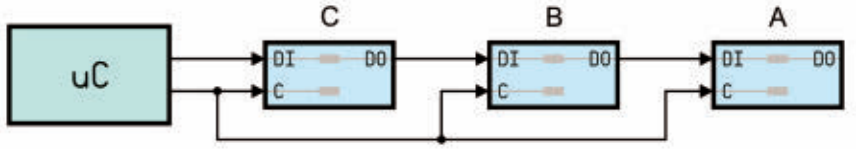
The WS2801 is a 5V device and the datasheet says that V_{IH} is VDD * 0.8 (4V) — how then, do we ensure proper communications between the Propeller and the WS2801? A solution that I particularly like is the Microchip TC4427. This neat little chip is designed for driving MOSFETs (which I've done), and I find it fantastic as an interface between 3.3V and 5V circuits — especially when the 5V side needs a bit of oomph. The TC4427 uses a push-pull driver which switches the outputs between GND and VDD. With a V_{IH} of 2.4V, it's an ideal interface device for the Propeller. **Figure 3** is the circuit that I've used in a number of applications.

SPINNING THE WS2801

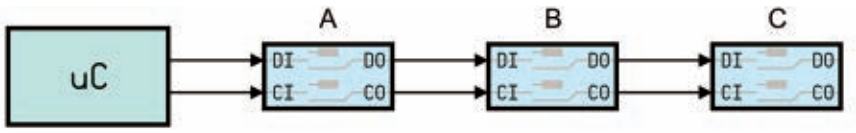
In the simplest terms, the WS2801 can be thought of as a specialized shift register with three eight-bit PWM outputs. It can be configured for constant voltage or constant current output, though the latter's configuration is typical in most LED applications. If you have experience



■ FIGURE 3. TC4427 schematic.



■ FIGURE 4. Shift register signal path.



■ FIGURE 5. WS2801 signal path.

with shift registers — the 74x595, for example — you may be concerned about writing code that deals with a large number of LEDs. I was, too, and here's why: With a typical shift register, the data for modules at the end of the chain have to pass through the modules at the head of the chain. What this means, of course, is that we need to know how many devices are connected to ensure proper data alignment.

Have a look at **Figure 4**. In this case, with three shift registers the bits for the device A must pass through the workings of devices B and C because the clock input on all the devices is tied together. Okay, not a big problem ... until there is a mismatch between the number of devices actually connected and the number of devices the driver is expecting to be connected. This is especially problematic when there are fewer devices connected than the software wants to shift data for.

A nifty feature of the WS2801 is that both the data and clock signals pass through the chip, and they do so in a switched manner. This is illustrated in **Figure 5**. When the clock line is idle for at least 0.5 ms, the device will switch such that it accepts the data and clock signals. After 24 bits are received (eight bits for each of the outputs), the data and clock signals are re-routed to the SDO and CKO pins and on to the next device. What this means is that the first 24 bits transmitted land in the device closest to the processor, the next 24 bits will land in the second device, and so on. If there are fewer modules connected than the software is attempting to write to, those modules will still get the correct values.

Okay, let's spin up some code. Whenever possible, I try to write a Spin driver just to learn my way around a new device. With the WS2801, this is pretty easy. If you've never written code for an SPI type device, you'll find this snippet useful:

```
pub refresh_ws2801 | idx, temp

  repeat idx from 0 to LAST_CH
    temp := color[idx] << 8
    repeat 24
      outa[SD] := temp <-= 1
      outa[CK] := 1
      outa[CK] := 0
```

The core of the routine is a simple loop that iterates through an array that holds the 24-bit color values. As the values are shifted MSB first, we will take the 24-bit value and shift it left by eight bits; this moves the 24-bit MSB to the MSB of the 32-bit long. Now, we drop into an inner loop that will clock out the 24 bits. The first line uses the rotate and assign operator (<-=) to move bit 31 to bit 0 which is then moved to the Propeller pin that connects to SDI. With the bit in place, we take the clock high then back low. Pretty easy, right? Yes, it is. When the LEDs arrived, I cut a short segment from the strip and connected them to an HC-8+ controller which has a built-in 3.3V-to-5V level shifter. I ran a simple test and got an unexpected result. I had filled the color array with $FF_00_00 and expected the LEDs to be red, but instead they were blue. It turns out that the module I have expects to receive the bits for the blue channel first.

While I don't like the phrase "*fix it in code*," I was left with no choice. With the following method, I could set any element in the array; it takes care of swapping the red and blue color bytes in the 24-bit value:

```
pub set(ch, rgb) | temp

  temp.byte[2] := rgb.byte[0]
  temp.byte[1] := rgb.byte[1]
  temp.byte[0] := rgb.byte[2]

  color[ch] := temp
  refresh_ws2801
```

It's interesting that Spin doesn't have dot notation for bits, but it does for bytes and words within a long. That said, this does not work on an array element; hence, the temporary variable in the code. The reason we swap the red and blue bytes is to allow hex values with this structure in our code:

```
$RR_GG_BB
```

I'm a very visual person, so this works for me — I can look at a value using hex notation and know what the constituent element values are. Once the color bytes are swapped in the working variable, it is moved into the array and the string is updated. Finally, it makes sense to allow for setting all colors in the array. That's easy, too:

```
pub set_all(rgb)| temp

  temp.byte[2] := rgb.byte[0]
  temp.byte[1] := rgb.byte[1]
  temp.byte[0] := rgb.byte[2]

  longfill(@color, temp, CHANNELS)
  refresh_ws2801
```

As you can see, there's only one line of code that differs; instead of moving to a specific element of the

array, we use **longfill** to move the value to all elements of the array. There have been times when I've been overly aggressive with code consolidation. For example, there have been times where I would have done this:

```
pub set(ch, rgb) |  temp

   temp.byte[2] := rgb.byte[0]
   temp.byte[1] := rgb.byte[1]
   temp.byte[0] := rgb.byte[2]

   if (ch => 0)
     color[ch] :=  temp
   else
     longfill(@color, temp, CHANNELS)
   refresh_ws2801
```

This variation will copy the color value to a single array element if that channel specified is zero or positive — which could be a valid array index. If the value is negative, then all elements are filled with the color.

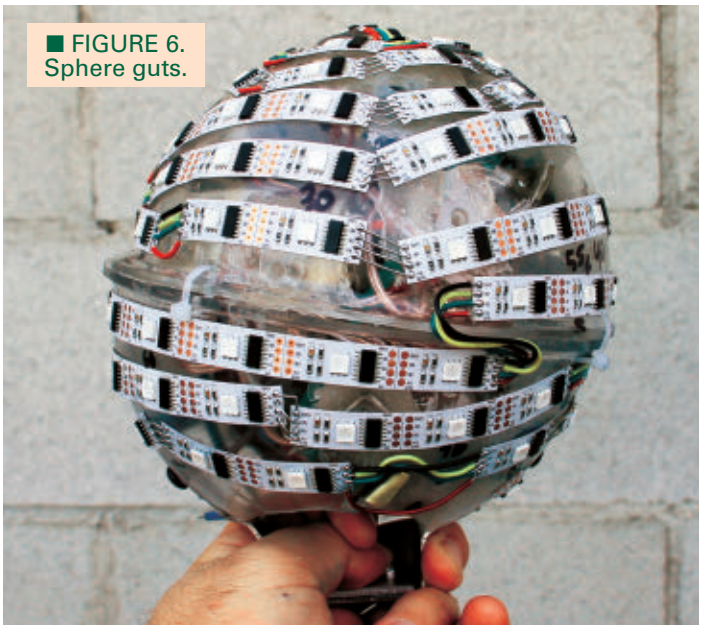
Use your own judgement here. For me, I tend to err on the side of blatantly obvious code — even if routines are a little redundant. Still, there will be times when memory is tight, and we can use these opportunities to reduce code size.

BUILDING A HIGH SPEED DRIVER

While I was working on the initial driver code, my friends at Biomorphs (Mike Deak and Cleve Gunderman) were constructing a plastic sphere to hold the LED strips. We cut the long strips into short segments, affixed them to the sphere in a spiral pattern from top to bottom, then soldered the strips back together (*yes, it was as much work as it seems*). In the end, we had 94 LED modules on the sphere which meant that a PASM driver would be useful for high speed animations. **Figure 6** shows the completed core; inside is an HC-8+ controller and illuminated mounting points that hold the outer (diffusion and decorative) shells in place.

The good news is that the PASM driver is about as easy to code as the Spin driver. Yes, I realize this is relative but as I have stated many times, Propeller assembly is one of the easiest to learn. I say this from personal experience. I generally don't like coding in assembly, but with the Propeller it's a joy. I'll save you the boring setup code; here's the core of the PASM driver that refreshes an RGB LED string with up to 170 modules:

```
rgbmain         mov     pntr, hub
                mov     count, nleds

getrgb          rdlong  t1, pntr
                add     pntr, #4

swaprb          mov     t2, t1
                and     t2, HX_00_FF_00

                mov     t3, t1
                and     t3, HX_00_00_FF
                shl     t3, #16
                or      t2, t3

                and     t1, HX_FF_00_00
                shr     t1, #16
                or      t2, t1

shiftout        shl     t1, #8
                mov     bits, #24
:loop           rcl     t1, #1          wc
                muxc    outa, sdimask
                nop
                or      outa, ckimask
                nop
                andn    outa, ckimask
                djnz    bits, #:loop

                djnz    count, #getrgb

                waitcnt frametimer, frame
                jmp     #rgbmain
```



■ FIGURE 6. Sphere guts.

At the top, we move the address of the color array (save in *hub*) to a temporary variable called *pntr*, then move the number LED modules to refresh to a variable called *count*. The code at the label **getrgb** is the top of the loop; at this point, we read a 24-bit color from the array, then advance the pointer by four (bytes) for the channel.

The next section isolates each byte and swaps the red and blue bytes for the channel. The corrected 24-bit color ends up in *t2*.

The real work happens at **shiftout**, and this directly mimics what we did in Spin. The first step is to shift the bits left by eight to align the color value MSB with bit 31. Next, we set a variable to 24 for the number of bits to shift. At the local label :**loop**, we rotate the value left by one bit, and leave what was in bit 31 in the Carry bit. The next line moves the Carry bit to the SDI pin by using a pin mask. I inserted a **nop** to allow the SDI output to settle before taking the clock line high and then back low. Note that there is also a **nop** after taking the clock line high.

After all the bits for the current channel are sent, we do the next channel, continuing until the entire array has been transmitted. At the end of the loop, we wait for a frame timer to expire before repeating the process. The value for this timer is specified in the **.start** method of the

object. How long should it be? Well, at a minimum it needs to be 10 microseconds (at 80 MHz) per RGB channel, plus one half millisecond to allow the appropriate clock idle period. In practical terms, this means we can update 170 RGB LEDs (what the final driver supports) in under three milliseconds.

Yes, that's pretty zippy, and works to our advantage once we start animating. So, let's go there, shall we?

PAINTING WITH LIGHT

With 24-bit control of every LED in the string, we can create any number of colors and color combinations; honestly, having this much freedom can become overwhelming. This is where starting simple and making time to "play" really pays off. On the Ryze project, I had been experimenting with creating light streaks using a simple algorithm. In my mind it was just a test, but when Steve saw it he "lit up" too. The behavior of the lights using the simple test code matched what he had been seeing in his mind's eye; well, at least part of it. Let's start with something simple that looks really nice: A color shift from one bold color to another. This process is very simple with byte color values. We can ramp one color from $FF to $00, and subtract the first color from $FF for the second; this causes the brightness of each color to be out of phase with each other. I created a simple support method which simplifies building a 24-bit RGB value:

```
pub make_rgb(r, g, b)

  return ((r & $FF) << 16) | {
  }       ((g & $FF) <<  8) | {
  }        (b & $FF)
```

The LEDs on the strip are remarkably bright, so I'm going to use the 50% point ($7F) as the maximum level. When you run this, you'll see the LEDs transition from green through cyan to blue and then back. It's actually quite soothing, especially when the LEDs are viewed under diffusion:

```
t := cnt
repeat
  repeat level from $7F to $00
    leds.set_all {
    } (make_rgb(0, level, $7F-level))
    waitcnt(t += (20 * MS_001))

  repeat level from $00 to $7F
    leds.set_all {
    } (make_rgb(0, level, $7F-level))
    waitcnt(t += (20 * MS_001))
```

Since we're approaching Christmas time, it might be nice to add a bit of sparkle to the animation by randomly selecting a single LED and briefly making it white. To make it really interesting, though, there should be random delays between the sparkle outputs.

Allow me to change the topic for just a bit. The Spin language has a random operator (?) and we must remember that this is not truly random — it is pseudo-random. Given the same seed, the output will be the same. This is fine when there is some external influence; for example, a value being randomized inside a loop while waiting on an external trigger.

Chip Gracey, the creator of the Propeller, created an object called RealRandom that exploits the natural jitter in the counter module's PLL circuitry to create a random value. The problem, though, is that this object uses a cog. To get around this, we can use the object to create a random seed and then shut it down, like this:

```
rr.start
lottery := rr.random
rr.stop
```

In this fragment, we're starting the RealRandom object, using it to provide the initial value to our global random number (*lottery*), and then we unload RealRandom to free that cog for other uses. What this ensures is that we'll get a different initial seed value in *lottery* at every start-up.

Since I spend a lot of time writing lighting and prop control programs, random is a big part of my programming practice. There are some real brainiacs that frequent the Propeller forum and one of them, Heater, did an analysis on the Spin random operator and found that the distribution was not as random as we would like. To solve this, he ported an excellent bit of C code to the Propeller and *bam*! — better random values. I know this is highly subjective, but in the programs I've written that need random values — candle flicker simulation, for example — the PRNG object produces better results. The object is very small; really just a few lines of code:

```
rr.start
prng.start
prng.seed(rr.random, rr.random, {
} rr.random, rr.random, rr.random)
rr.stop
```

This process gives us excellent random values using very little code and does not require full time use of another cog, so it is now part of my prop control template. Okay, how do we go about adding a random sparkle to the LEDs that are presently washing back and forth between blue and green? While we could modify the fade loop, that becomes very complicated, makes a mess of timing, and just makes the code harder to adjust later. While working with Steve on the Ryze project, I wrote a number of Spin methods that I could launch into their own cogs to run independently. This allowed me to easily switch elements and fine-tune them so the overall effect worked as Steve wanted.

Here's a routine that will randomly flash one of the

PARTS LIST

ITEM	DESCRIPTION	SOURCE
C1	0.1 µF	Mouser 80-C315C104M5U
R1-R2	10K, 1/8W	Mouser 299-10K-RC
U1	TC4427	Mouser 579-TC4427CPA

LEDs white for 100 ms, and then wait 250 ms to one second before doing the next. If we have 32 or fewer LEDs and we want to ensure that all have flashed before repeating, we can add what I call a "play list" to the code:

```
pri sparkler | playlist, last, ch, delay

  playlist := %00000000
  last := -1

  repeat
    repeat
      ch := (prng.random >> 1) // CHANNELS
      if (playlist & (1 << ch) == 0)
        if (ch <> last)
          playlist |= (1 << ch)
          if (playlist == %01111111)
            playlist := %00000000
          last := ch
          quit

    leds.set(ch, $FF_FF_FF)
    pause(100)

    if (ch == 0)
      leds.set(0, leds.read(1))
    else
      leds.set(ch, leds.read(0))

    delay := (prng.random >> 1) // 751 + 250
    pause(delay)
```

Let me give you an overview before diving into the details. This method generates a random channel value. If that channel has not "sparkled" this cycle (all channels flashed) and it's not a repeat of the channel from the last cycle, we then mark it, flash it, and create a random delay.

The PRNG object returns signed values so we can remove the sign by shifting the output right by one bit. Then with the modulus operator (//), we end up with a proper channel value between 0 and the number of channels minus one. This value is used to create a mask that is ANDed with the playlist to ensure that this is a new channel. If that passes, there is a final test to ensure we don't flash the same output twice in a row.

When we have a valid channel, we add it to the playlist by ORing with the same mask, and then checking to see if this is the last channel for this cycle (i.e., the playlist is full). Note that in my program I have only seven LEDs in my test strip, so you'll have to adjust for yours.

JON "JONNYMAC" WILLIAMS
jon@jonmcphalen.com

RESOURCES

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EFX-TEK
HC-8+ controller
www.efx-tek.com

MINION'S WEB
LED strip with the WS2801
www.minionsweb.com

SPARKFUN ELECTRONICS
WS2801 break-out module
www.sparkfun.com

Once we have a good channel and the *playlist* and *last* variables are updated, we drop out of the inner loop to the flash section. Please feel free to play with and modify this as you desire. I can tell you that the strategy works very nicely and I've used it to control everything from the random function in a commercial audio player to pop-up gophers in a children's ride at a big theme park.

Most of you have detected a problem with this code even before seeing it run: We set the flash timing to be 100 ms but that will never happen as this code is written. Why? Because the foreground cog is updating the green-blue color wash every 20 milliseconds. How do we fix this? Here's an easy way — if, perhaps, a tad brute force:

```
    repeat 100
      leds.set(ch, $FF_FF_FF)
      pause(1)
```

What we're doing here is updating the 'flash' LED every millisecond so that we can quickly overwrite any changes made by the foreground. While more involved, there is another strategy that I tend to favor — especially when there are multiple animation layers and I want to assign which gets priority during conflicts. This process involves creating temporary color buffers for each animation cog. We'll start by modifying the sparkle method/cog so that it writes to the *cbuf2* array instead of the WS2801 driver (this is just the last bit of code):

```
    cbuf2[ch] := $FF_FF_FF
    pause(100)

    cbuf2[ch] := -1
    delay := (prng.random >> 1) // 751 + 250
    pause(delay)
```

Note that we're using -1 for "no color" as $00_00_00 is valid (off). Now for the foreground loop:

```
t := cnt
repeat
  repeat level from $7F to $00
    color := make_rgb(0, level, $7F-level)
    repeat ch from 0 to LAST_CH
      if (cbuf2[ch] < 0)
        cbuf1[ch] := color
      else
        cbuf1[ch] := cbuf2[ch]
    longmove(leds.address, @cbuf1, CHANNELS)
    waitcnt(t += (20 * MS_001))

  repeat level from $00 to $7F
    color := make_rgb(0, level, $7F-level)
    repeat ch from 0 to LAST_CH
      if (cbuf2[ch] < 0)
        cbuf1[ch] := color
      else
        cbuf1[ch] := cbuf2[ch]
    longmove(leds.address, @cbuf1, CHANNELS)
    waitcnt(t += (20 * MS_001))
```

In this version, we write the new shifting color to the *cbuf1* array, but only if there is a -1 in the corresponding channel of *cbuf2*. What this does is give priority to *cbuf2*. After *cbuf1* is built, we can copy it to the WS2801 driver using the **longmove** with the driver's .**address** method.

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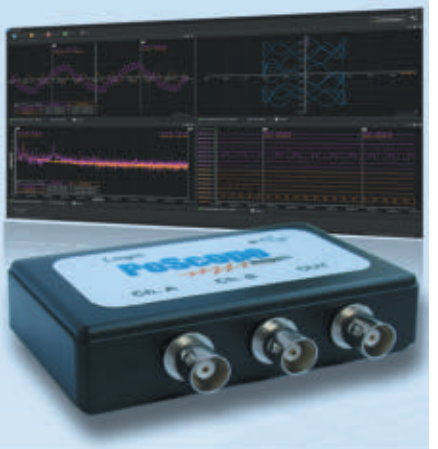

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■ FIGURE 7. Ryze on display at PAX 2012.

There you have it. As I've learned from my friends in Hollywood make-up and effects, sophisticated art is built up layer by layer. By using temporary buffers as in the final example, we can have a number of independent animations running and decide which gets priority for final output. As with any art, it does take time and a lot of play. Yes, there's that four letter word again, but I truly believe in it. **Figure 7** shows the final result for Ryze that Steve and his team produced. Of course, a picture cannot show the work we did on the lighting animation. Search YouTube for my stage name (Jon McPhalen) and you'll find a bit of video from the shop while we were working on the character.

HAPPY HOLIDAYS!

Okay, the Christmas season is nearly on us, so whether you've got a single RGB LED or a whole pack of them, the WS2801 provides an excellent means of control. It's time to hook them up and start playing.

Thanks for all the kind notes and feedback through the year, and please accept my very best for you and your family this holiday season and forthcoming new year. Until next year, keep spinning and winning with the Propeller! **NV**

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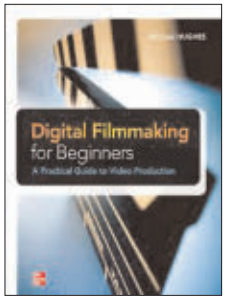

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Programming Arduino Getting Started with Sketches
by Simon Monk

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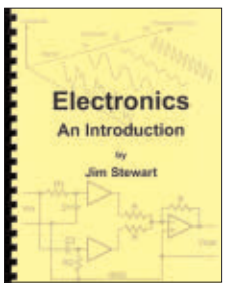
Electronics An Introduction
by Jim Stewart



This book is designed as an in-depth introduction to important concepts in electronics. While electronics can be highly mathematical, this text is not about calculations. It is about how electronic equipment is able to extract, process, and present information held in electrical signals. If you are in — or studying to be in — a profession that requires the use of electronic equipment, then this book will provide the insight necessary to use such equipment effectively.
$33.95*

Build Your Own Electronics Workshop
by Thomas Petruzzellis

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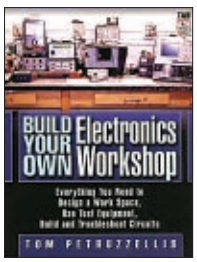

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by Thomas Kibalo

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by Fred Eady

Master and Command C for PIC MCU, Volume 1 aims to help readers get the most out of the Custom Computer Services C compiler for PIC microcontrollers. The author describes some basic compiler operations that will help programmers particularly those new to the craft create solid code that lends itself to easy debugging and testing. As Eady notes in his preface, a single built-in CCS compiler call (output_bit) can serve as a basic aid to let programmers know about the "health" of their PIC code.
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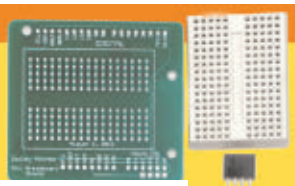

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PROJECTS

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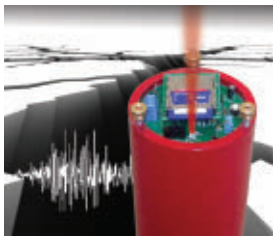

As seen in the May 2012 issue. Now you can record your own shaking, rattling, and rolling.

The Poor Man's Seismograph is a great project /device to record any movement in an area where you normally shouldn't have any. The kit includes everything needed to build the seismograph. All you need is your PC, SD card, and to download the free software to view the seismic event graph.

Subscriber's Price **$79.95**
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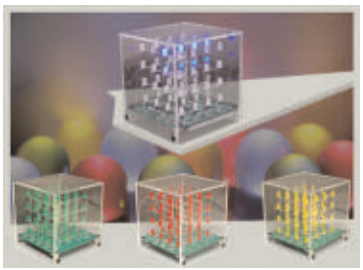
3D LED Cube Kit



This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes.
Colors available: Green, Red, Yellow & Blue

Subscriber's Price **$57.95**
Non-Subscriber's Price **$59.95**

Battery Marvel Kit

As seen in the November 2011 issue. Battery Marvel helps protect cars, trucks, motorcycles, boats, and any other 12V vehicles from sudden battery failure. This easy-to-build kit features a single LED that glows green, yellow, or red, indicating battery health at a glance. An extra-loud piezo driver alerts you to any problems.

For more info, please visit our website.

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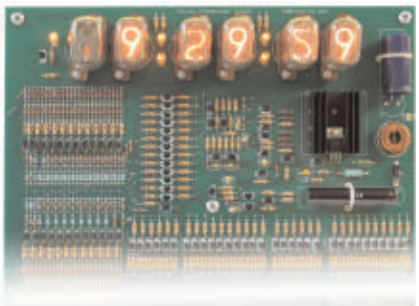
Neon Transistor Clock Kit



Add HIGH VOLTAGE to your clock!
This is a Nixie Tube display version of the Transistor Clock. It uses only discrete components — no integrated circuits. For more info, see the April 2012 issue.

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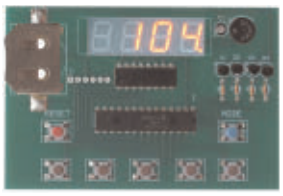
Sorting Counter Kit

As seen in the July 2011 issue.



Sorting counters have many uses — keeping score, counting parts, counting people — it is just a handy gadget to have around. This is a very simple project for those who want to learn to solder or are interested in using microprocessors and how they function. No special tools are needed, just a small tip soldering iron. It has no box as it stands alone, therefore there is no drilling.

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Non-Subscriber's Price **$39.95**

Magic Box Kit

As seen on the April 2007 cover.

This unique DIY construction project blends electronics technology with carefully planned handcraftsmanship. This clever trick has the observer remove one of six pawns while you are out of the room and upon re-entering you indicate the missing pawn without ever opening the box.

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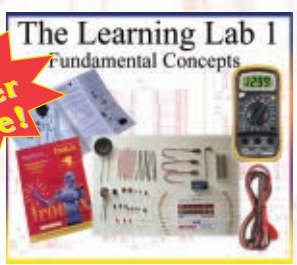

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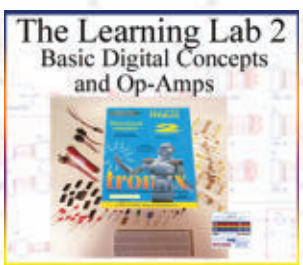

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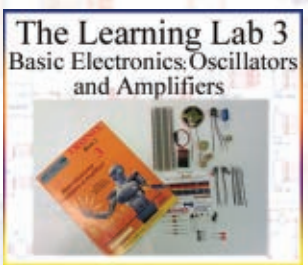

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The labs in this series — from GSS Tech Ed — show simple and interesting experiments and lessons, all done on a solderless circuit board. As you do each experiment, you learn how basic components work in a circuit, and continue to build your arsenal of knowledge with each successive experiment.

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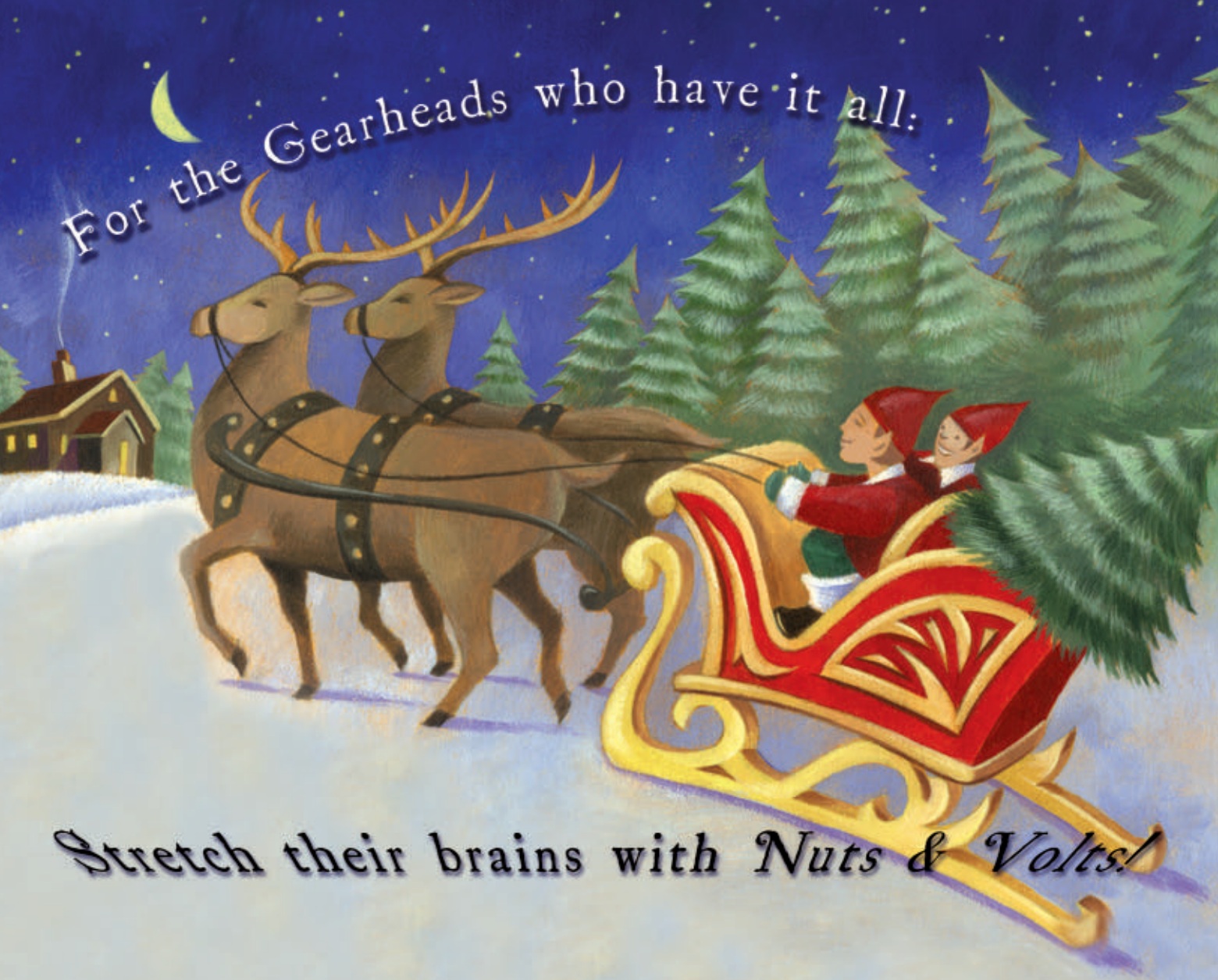

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THE DESIGN CYCLE

■ BY FRED EADY

ADVANCED TECHNIQUES FOR DESIGN ENGINEERS

GIVE YOUR DATA RADIO THE AX8052F100

Behind every good data radio, you will find a microcontroller filled with tricky radio driver firmware. In most cases, the microcontroller that supports the data radio moonlights as the LCD controller, the RS-232 driver, and the analog interface. These days, you can pick and choose from a variety of general-purpose and niche microcontrollers. There are microcontrollers that specialize in motor control and those that excel in number crunching. In this installment of Design Cycle, we are going to closely examine a microcontroller that was designed to drive RF ICs.

THE AX8052F100

As its name implies, the AX8052F100 is based on the tried and true 8052 microcontroller core. It comes wrapped in a tiny 28-pin QFN package. The typical data radio does not have the luxury of consuming power on a regular basis. So, to be able to eat when the radio eats, the microcontroller in charge of the radio station must have as low or lower power consumption figures than the radio itself.

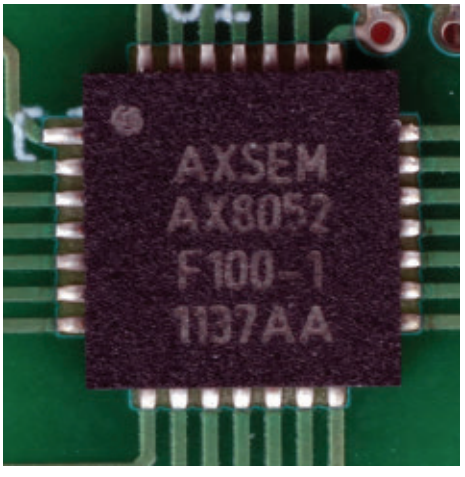
The AX8052F100 low power modes include standby, sleep, and deep sleep. The AX8052F100 sleeps at 850 nA, 1.5 µA, or 2.2 µA, depending on how much of its RAM you wish to protect while its eyes are closed. The RAM retention sleep numbers coincide with 256 bytes, 4 KB, and 8 KB of system RAM. When the AX8052F100 is actively computing, the current draw is based on the microcontroller clock speed. Typically, it burns 150 µA per MHz.

The AX8052F100's system clock can be generated externally or internally. You can hang a 32.768 kHz tuning fork crystal on the low power crystal oscillator pins or a 20 MHz crystal on the AX8052F100's XTAL pins. A 20 MHz clock can also originate from the AX8052F100's internal 20 MHz RC oscillator.

If your data radio application needs to be cheap and stingy, you can call upon the AX8052F100's 10 kHz/640 Hz super low power internal RC oscillator. To a data radio, timing is everything. So, the AX8052F100 allows you to calibrate the on-chip RC oscillators using a reference clock signal.

Don't let the AX8052F100's size fool you. The tiny QFN package packs 64 KB of wear-resistant program Flash which can withstand 100,000 erase cycles. There is 8.2 KB of RAM available for manipulating those incoming and outgoing data packets. The memory map of the AX8052F100 follows that of the legacy 8052 cores. So, everything you have learned about the 8052 over the years can be applied directly to the AX8052F100.

The AX8052F100 only has 28 pins to work with. To accommodate the UART, SPI, analog-to-digital



■ PHOTO 1.Don't fear the AX8052F100's QFN package! We've experienced laying them down on copper-clad fiberglass before (Design Cycle March 2009 issue).

converter (ADC), and analog comparator peripherals, its pins can be configured to act as peripheral I/O or general-purpose I/O pins. If you take a look at the AX8052F100 datasheet, you won't find a ground pin. To further conserve I/O pins, the AX8052F100's ground pin is actually the exposed pad on the underside of the QFN package.

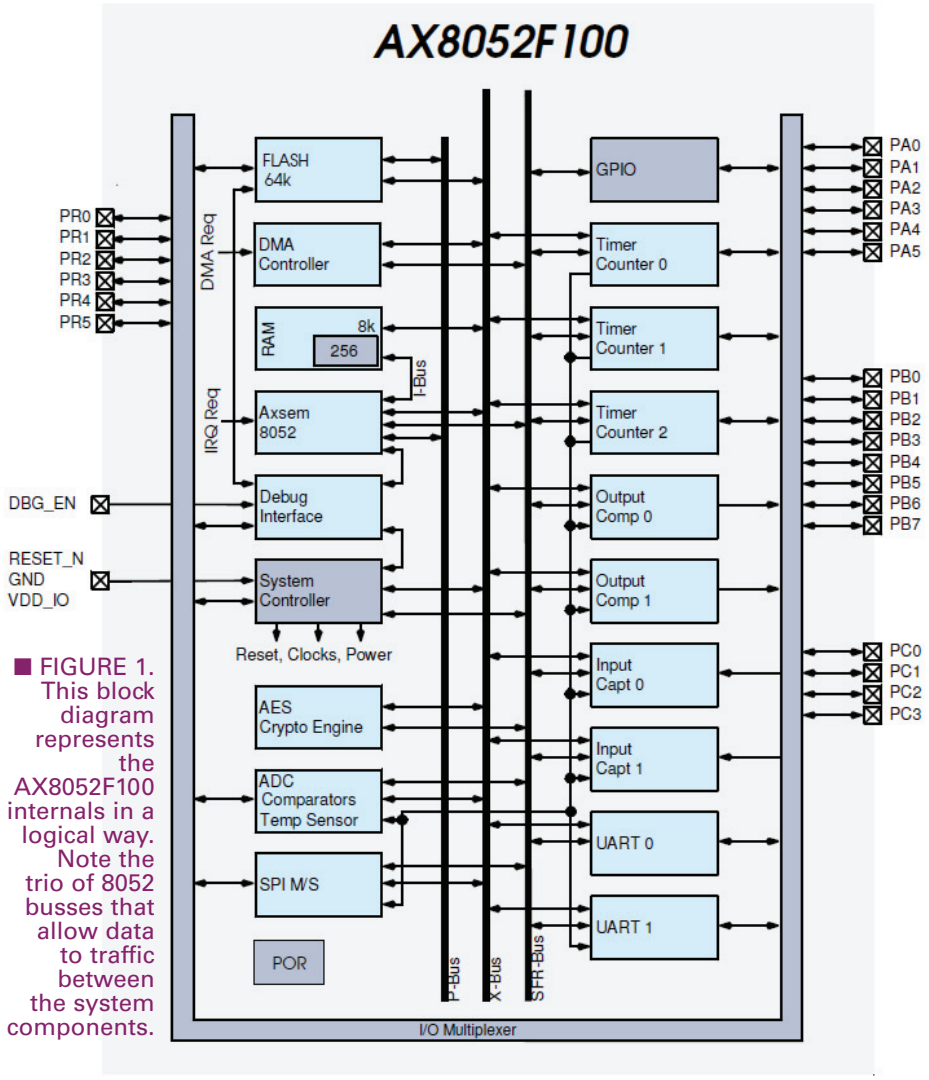
What would any microcontroller do without its internal timers? The AX8052F100 contains three 16-bit general-purpose timers. The timers can be used in conjunction with the pair of 16-bit output compare units to generate PWM signals. The timers can also be used to assist the pair of 16-bit input capture units in timing events based on internal and external signals.

Conserving power is great. However, if the AX8052F100 goes to sleep and can't wake up, you might as well not have it working for you at all. To assure wake-ups, the AX8052F100 is equipped with a pair of 16-bit wake-up timers.

In some microcontroller data radio applications, time is money. So, the AX8052F100 is equipped with an on-chip DMA engine to transport data between its internal logic blocks with minimal assistance from the CPU. If that data you're moving is super-secret and has to leave the confines of the AX8052F100, its dedicated AES crypto engine can be called upon to secure the data.

Specialization comes into play on the AX8052F100's radio interface I/O pins which are located between pins 1 and 7. The AX8052F100's radio interface is actually a dedicated SPI portal which is designed to drive the ASXEM RF ICs. The AX8052F100's radio SPI portal can also be used to drive any other data radio that interfaces to a host microcontroller using SPI. If you don't wear a pointy hat adorned with quarter moons and stars, you can turn off the AX8052F100's radio interface and employ the pins as general-purpose I/O.

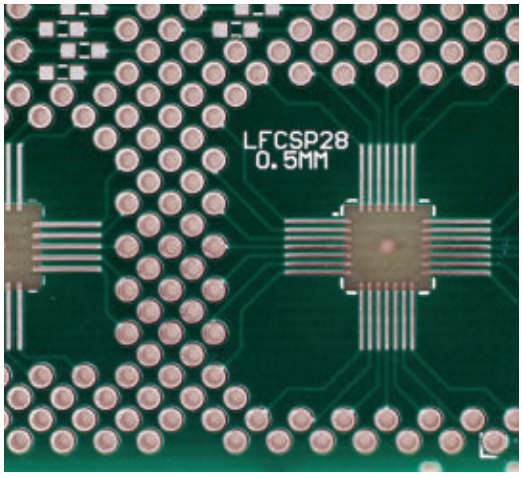
Need temperature data? The AX8052F100 can supply it via its on-chip temperature sensor. There is also a one volt internal ADC reference that allows you to measure the voltage at the VDDIO pin. Rather than go into a lengthy description of how the AX8052F100's peripherals, ADC, and logic blocks intertwine, I give you **Figure 1** and **Figure 2**. **Figure 1** is a satellite view of the AX8052F100's CPU, memory, and peripheral resources, while **Figure 2** shows how its analog peripherals are interconnected. A loose AX8052F100 is showing its teeth in **Photo 1**.



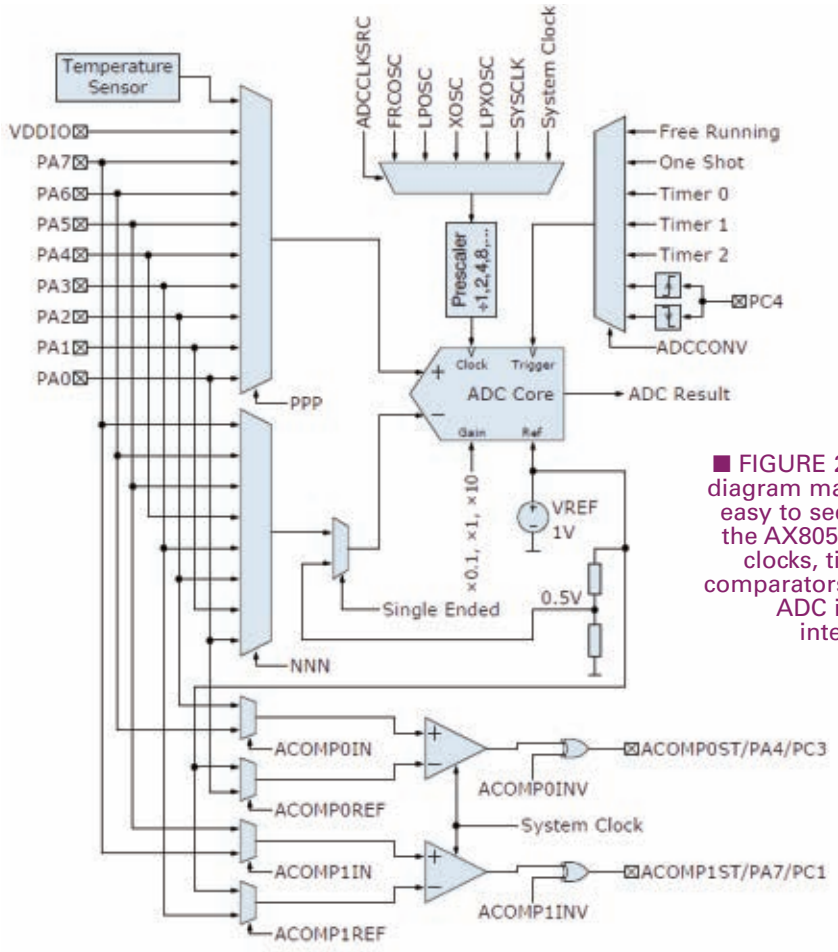
■ FIGURE 1. This block diagram represents the AX8052F100 internals in a logical way. Note the trio of 8052 busses that allow data to traffic between the system components.

AX8052F100 101

We can talk about the AX8052F100 and its features all day long. However, that's not why you are reading this. You are most likely here because you are interested in applying the



■ PHOTO 2. A QFN pit is formed by eliminating a section of PCB coating that is the size of the QFN package. The resultant pit helps to perfectly align the QFN device pins to the SchmartBoard's PCB pads.



■ FIGURE 2. This diagram makes it easy to see how the AX8052F100 clocks, timers, comparators, and ADC inputs interplay.

AX8052F100 datasheet contents. So, I decided to put together a minimal AX8052F100 embedded system.

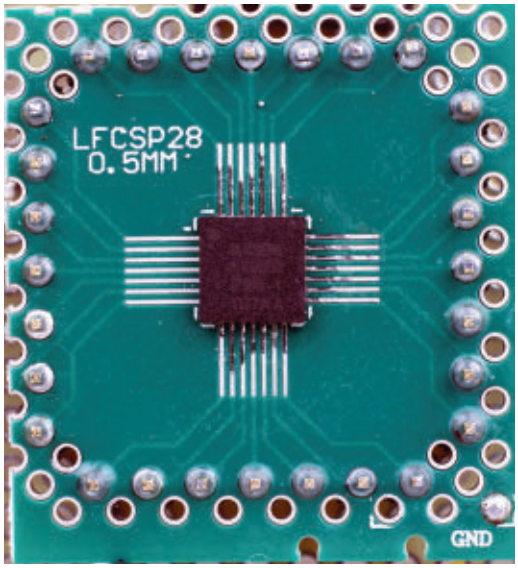
We have worked with QFN packages before. Reference the March 2009 Design Cycle column in which we designed and scratch-built a QFN-based USB interface. This go-round, we're going to work "Schmarter" not harder.

The folks at SchmartBoard offer a very clever way of mounting various QFN packages. Take a look at **Photo 2**. Notice the absence of the printed circuit board (PCB) coating in each QFN body area. The size of the removed PCB coating matches that of the package size of the associated QFN part we wish to mount. Note also that the QFN interface leads are formed to allow it to be cradled in the bare pit.

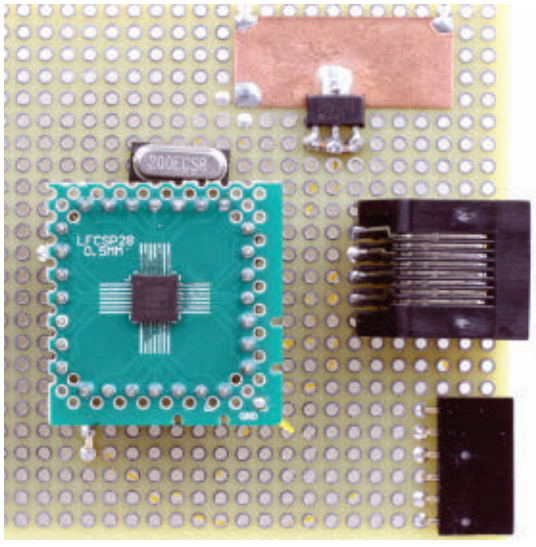
When placed in the pit, the QFN device's pins are aligned perfectly with the SchmartBoard's QFN PCB traces. How cool is that? **Photo 3** is a photographic capture of an AX8052F100 in the pit.

My minimal design is graphically depicted in **Schematic 1**. All of the radio-related SPI portal pins are aligned on the left side. The debug/programming interface is situated on the right quarter of the AX8052F100. The debugging interface is composed of the DBG_EN, DBG_CLK, and DBG_DATA signals. The PB3 I/O pin is used by the debugger to awaken the AX8052F100 from deep sleep. The crystals and associated capacitors are optional equipment. Just for grins, I decided to include a 20 MHz crystal in our design.

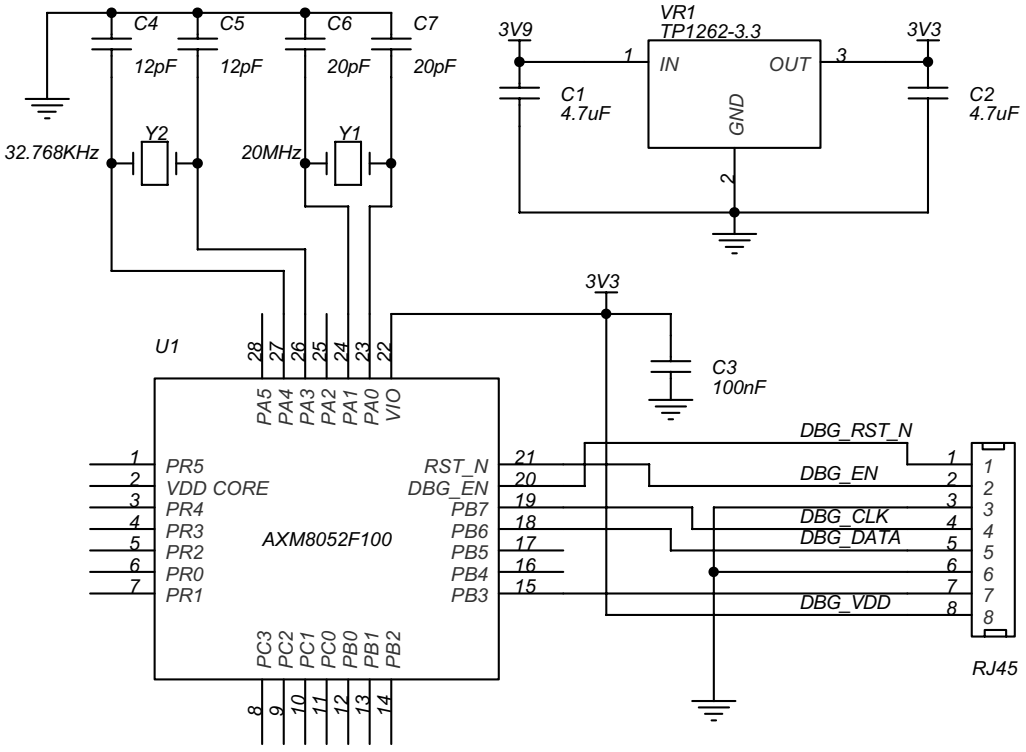
The hardware that is presented graphically in **Schematic 1** is physically represented in **Photo 4**. I trimmed the SchmartBoard before mounting the AX8052F100 in the pit. The SchmartBoard pad that electrically contacts the AX8052F100's exposed pad is isolated from the PCB's common ground plane. So, I scratched off some of the coating that surrounds the isolated pad and



■ PHOTO 3. This shot shows the AX8052F100 mounted in the SchmartBoard QFN pit.



■ PHOTO 4. A little bit of slicing and dicing plus some solder, wirewrap wire, and sockets make up our minimal AX8052F100 hardware design.



■ SCHEMATIC 1. This is as basic as it can get. The RJ45 connector is used to interface with the AXSEM AXDBG debugger.

made an electrical connection between it and the ground plane. I also placed a dab of solder into the hole at the center of the QFN pit to make sure the AX8052F100's exposed pad had an electrical path to ground via the isolated pad, which is now a grounded pad.

In this design, the AXSEM AXSDB debugger supplies power to the AX8052F100 by way of pin 8 of the RJ45 connector. The incoming 3.9 volts is regulated by the Microchip 3.3 volt voltage regulator (VR1).

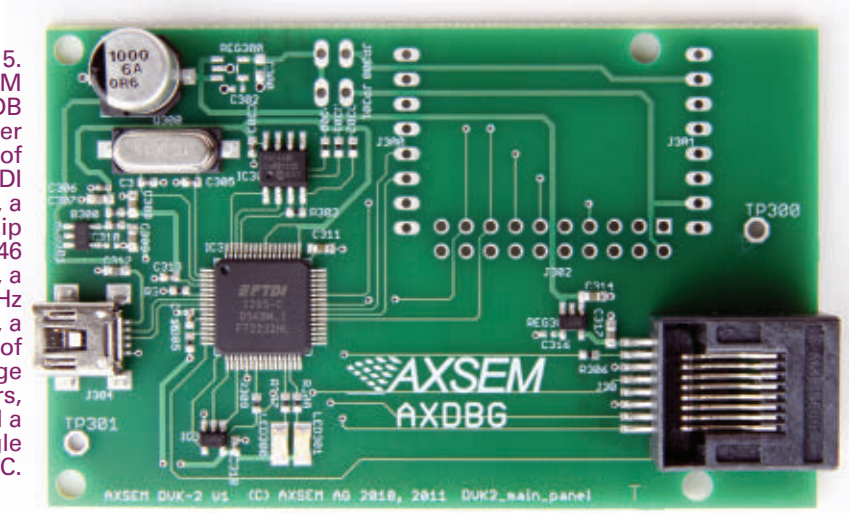
THE AXSEM AXSDB DEBUGGER

Our minimal AX8052F100 system will take its orders from the AXSEM AXSDB debugger until it is able to walk on its own. The AXSDB debugger you see in **Photo 5** is based on an FTDI FT2232HL dual UART/FIFO converter. The +5.0 volts supplied by the USB host is initially converted to 3.3 volts by the first voltage regulator. The 3.3 volt power rail also supplies power to the Microchip 93C46 EEPROM which is driven by the FT2232HL. In our case, the USB-supplied +5.0 volts is also used to drive the debugger target. To be sure that a stable 3.3 volts results at the AX8052F100's power pin, a 3.9 volt voltage regulator is used to drive the target's incoming voltage regulator.

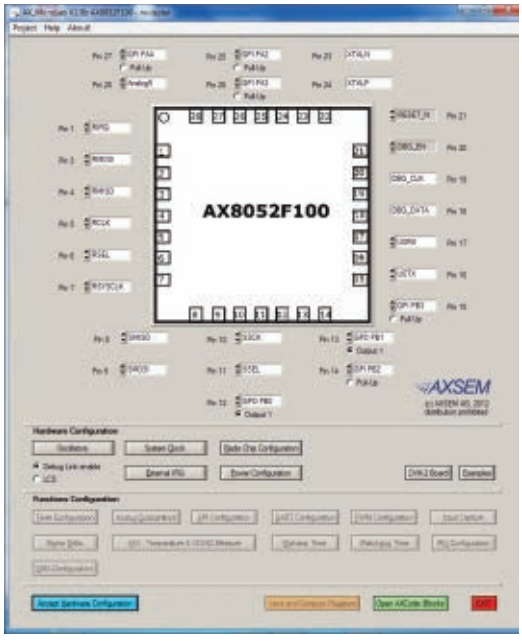
Judging from the debugger schematic — which can be obtained from the AXSEM website — the debugger data line (DBG_DATA) is bidirectional. So, to allow the FT2232HL to read and write the DBG_DATA pin, a tri-statable buffer is used to drive outgoing data on the DBG_DATA pin. Tri-stating the buffer allows incoming data to reach the FT2232HL uninhibited.

The debugger operates under the control of AXCode::Blocks which drives the FT2232HL using the FTDI D2XX direct driver. The debugger comes preloaded with an FTDI template that configures the FT2232HL's I/O subsystem.

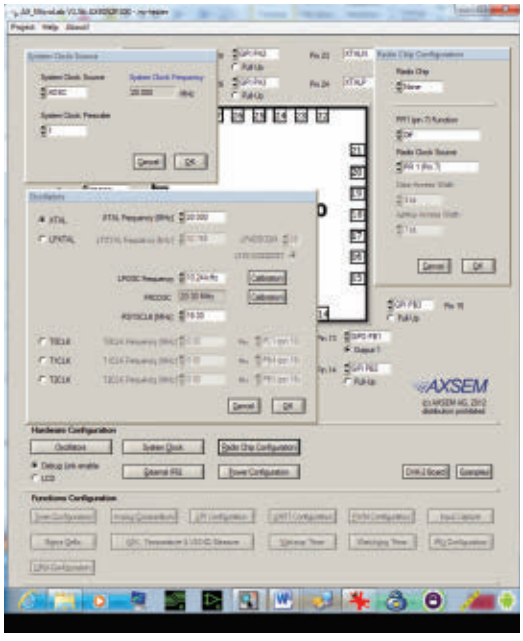
The debugging interface is enabled when the DBG_EN is driven logically high. Once it's enabled, I/O pins PB6 and PB7 relinquish their jobs and become dedicated debug interface pins. If the design uses PB6 and PB7 as I/O pins, the debugger software allows PB6 and PB7 to be set via an emulation feature. The emulation feature also allows the debugger software to read the pins



■ PHOTO 5. The AXSEM AXSDB debugger consists of an FTDI FT2232HL, a Microchip 93C46 EEPROM, a 12 MHz crystal, a couple of voltage regulators, and a single buffer IC.



■ SCREENSHOT 1. If it's part of the AX8052F100, you can tweak it from here.



■ SCREENSHOT 2. Using AX-MicroLab is akin to going to the supermarket with unlimited funds.

and set their I/O direction (input or output).

A form of code protection comes in the guise of a 64-bit key that can be selected by the AX8052F100 designer. Without the 64-bit key, the AX8052F100 firmware cannot be accessed via the debugger portal.

The AX8052F100 can be pushed into factory state using the secure erase feature. The 64-bit key is not needed to initiate a secure erase. Secure erase completely erases the AX8052F100's program Flash before erasing the 64-bit key.

AX-MICROLAB

It's all starting to come together. We have AXCode::Blocks to assist in the firmware development process. We've assembled a minimal AX8052F100 embedded system and our design can be programmed and debugged.

AXSEM provides yet another tool to take some more of the pain out of the AX8052F100 development process. AX-MicroLab is a software tool that runs on a PC and it allows the user to configure all of the AX8052F100's available features.

Take a look at **Screenshot 1**. I've created a configuration project called nv-tester which is based on our minimal AX8052F100 design. You can get lots of information about our design by simply examining the I/O pin configuration. For instance, pins 23 and 24 tell you that I'll be driving the AX8052F100 with an external clock source. Notice that the dedicated RESET_N and DBG_EN pins are nailed shut. If I had some sort of radio attached, the radio interface pins (1 through 7) would be locked in, as well.

In that we have no radio in our initial design, the radio interface pins are up for grabs; I didn't bother to set them up as general-purpose I/O. Rotating counterclockwise around the AX8052F100, you can see that I've configured a SPI portal on pins 8, 9, 10, and 11. While your eyes are in the SPI portal area, note that I've configured PC3, PB0, and PB1 to output a logical high on startup.

Moving to the far right quadrant of the AX8052F100, there are clues as to a potential serial port coming to this design. It's also pretty obvious that I have enabled the debugger interface. Finally, PA5 has been assigned analog input duty.

It's not enough just to perform the AX8052F100 pin assignments. If a pin is selected to do something other than general-purpose I/O, you may need to give AX-MicroLab a bit more information. For instance, in **Screenshot 2** I've specified that the external oscillator runs at 20 MHz and is the system clock source. Even though I didn't assign alternate duties to the radio SPI portal pins, I did take the time to release them by not defining a particular radio IC.

Clicking on the Accept Hardware Configuration button gives us access to the Functions Configuration buttons. In **Screenshot 3**, I completed the SPI portal setup by enabling the portal as a master running under the system clock at 1.25 MHz. The UART configuration has been altered to run with an eight-bit word and one stop bit at 9600 baud. Recall that the AX8052F100 can measure temperature and its incoming supply voltage. I've set that up in the ADC Settings window along with assigning the ADC type and gain. Note also that the ADC is free running and is set up to take 38.15 samples every second.

We've done the easy portion of the AX8052F100 setup. Clicking on the Save and Compute Registers button creates the code behind our selections. AX-MicroLab creates a function called *ax8052_set_registers* and another called *ax8052_setup*. I've captured a portion of each function

Lemos International
AX8052F100
AXSDB Debugger
www.lemosint.com

AXSEM
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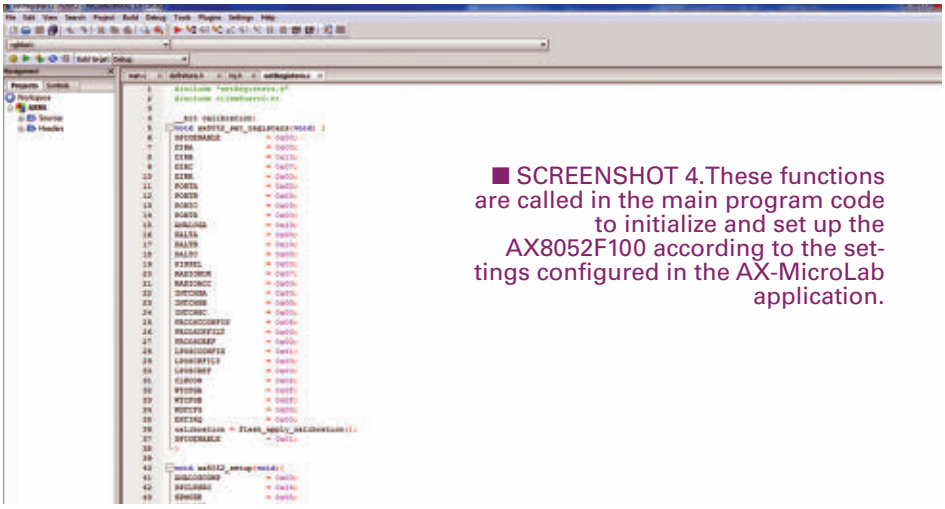
www.axsem.com

in **Screenshot 4**. As you can see, the *ax8052_set_registers* is concerned with things like setting up the direction of the AX8052F100's I/O ports. The *ax8052_setup* function takes care of the AX8052F100's functional blocks. For instance, the UART is initialized inside of the *ax8052_setup* function. If you turned on the debug interface, that too is initialized and started from within *ax8052_setup*.

In addition to building the *ax8052_set_registers* and *ax8052_setup* functions, AX-MicroLab generates nine additional example files. The idea behind the example files is to show you how to write the C source code to manipulate a number of the AX8052F100's resources. In that the AX8052F100 startup code is also part of the example code, you can use the examples to seed your home-grown applications.



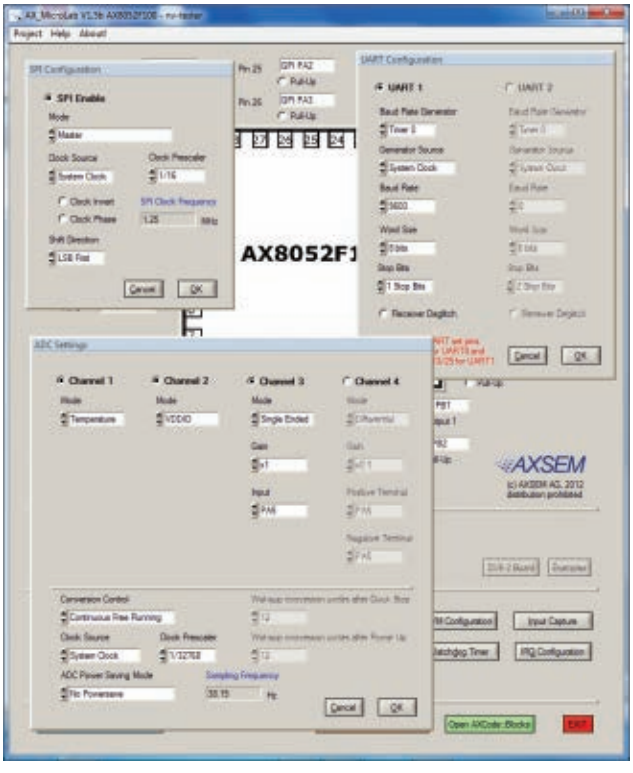
■ SCREENSHOT 4.These functions are called in the main program code to initialize and set up the AX8052F100 according to the settings configured in the AX-MicroLab application.

WHAT'S NEXT

Although the SchmartBoard was there for us this time, we will have to eventually build up our AX8052F100 on a professionally manufactured PCB. So, if that's the case, I'll think about what other goodies we can add to our board.

I also want to further examine the example firmware and the AX8052F100 firmware library. After all, we've got a SPI portal, a UART, and some ADC circuitry that needs to be exercised.

Once we get our AX8052F100 legs under us, we'll be one more step closer to scratch-building our integrated AXSEM radio and earning the privilege of wearing that pointy hat. **NV**



■ SCREENSHOT 3. This beats the heck out of sifting through the AX8052F100 datasheet and programming manual for bit settings.

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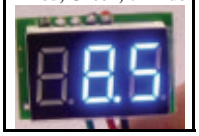

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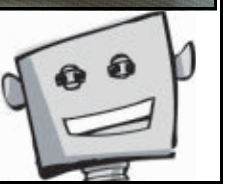

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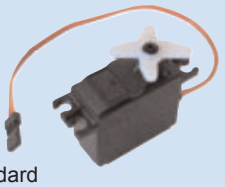

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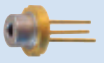

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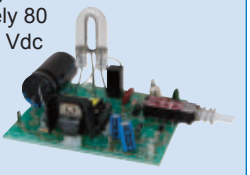

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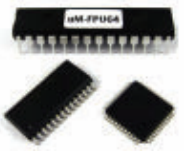

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>>> ANSWERS

[#9126 - September 2012]
1960's Tube Amp Volume Control Behavior

When I was in high school, there was a Newcomb institutional phonograph – 12 inch speaker and vacuum tube circuitry. My friend pointed out that when the volume control was not rotated clockwise far enough, the music was "thin." There came a point, however, that with further rotation of the volume pot the sound became full and lush. I would love to know what was going on in the circuit to cause that behavior.

#1 If I understand you, this may be because of the hearing response to various frequencies at different loudnesses. (See Fletcher Munson curves on Wikipedia.) Essentially, the ear hears the middle frequencies in the audible range better than the highs and lows at low volumes. At higher volumes, hearing response gets flatter and flatter.

Older sound systems did not have a way of compensating for this except manually with base and treble controls. Some modern ones may, but I don't see how because the sound pressure level is so dependent on loudspeaker efficiencies, which now can range from a fraction of 1% for compact speakers to 20% or so for a full-sized corner Klipsh.

Thus, systems in which the amp is sold separately from the speaker cannot know where the sound power level will be. The old system you speak of had a specific built-in speaker and thus would not have suffered that problem. Therefore, the thinness of the sound you heard at low volumes could well have been pure Fletcher Munson effect.

It should be noted (as it is on Wikipedia) that those curves have been refined some in later years, but the phenomenon still exists pretty much as described by Fletcher and Munson. I do not see why a solid-state amp would not exhibit the same phenomenon.

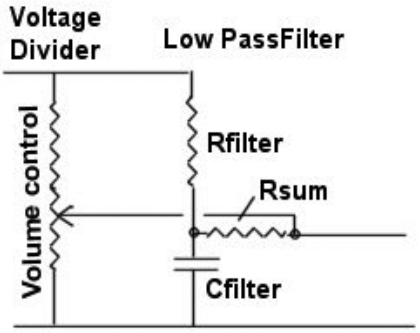
Jwdrake
Via email

#2 The circuit probably employed a tapped potentiometer (volume control). After the wiper passed a certain point on the control -- usually the center point on the range -- circuitry connected to the tap became the dominant factor in determining frequency response.

Peter A. Goodwin
Rockport, MA

#3 The "thin" sound being described is not due to a circuit, but due to the fact that our ears hear lower and higher frequency sounds less well at lower volumes. A search of the net on "Fletcher Munson" will show the typical contours.

That said, the question becomes: How do we compensate for it? In audiophile equipment, a tapped volume control and a loudness compensation circuit (or digital equivalent) are the preferred method. However, it is easy to retrofit existing equipment to provide very good compensation.



The image shown here is a model of a volume control circuit with loudness compensation. Consider the volume control to be an attenuator as a signal source to the next stage, and the low pass filter to be a second signal source.

In practical application, a 100K volume control is typical. At higher frequencies, the Cfilter is essentially a short circuit so we need to be mindful of the lower impedance load on the previous stage. In practicality, I find that an Rfilter of 12K to 18K, and Cfilter of .056 µF to .082 µF work well. Rsum may be from 39K to 120K.

In my 70's Technics receiver, I used values of Rfilter = 12K, Cfilter = .056 µf and Rsum = 120K. This results in excellent tonal balance at virtually all volume levels. If I want a warmer tone reminiscent of vintage Grundig tube radios, I either reduce the Rsum or pick a corner frequency that provides more lower mid-range boost

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at lower volumes.

Scale values appropriately based on the volume control resistance value. Starting off with trimpots for the Rsum and Rfilter is recommended to get the tone effect (or perceived flatness across volume levels) to that desired.

Jim Lacenski
Bellevue, WA

#4 I suspect that the speaker cone is warped and sticking. It doesn't produce much sound until the power is enough to break it loose, then it sounds okay.

Russ Kincaid
Milford, NH

[#9129 - September 2012]
My FM Radio Hates My New High Output Fluorescent Lighting

I have installed some 8' HO fluorescent lights, and now the FM radio has too much noise.

I put four snap-on RF chokes on the power cord at the radio. They did reduce some of the interference and I even plugged the line into a surge protector.

Is there anything I can do at the fixtures to knock out this RF problem?

#1 The first question that comes to mind is if Mr. Robin is 100% certain that the interference is on the power line side of things.

Generation of RF energy at 90 MHz these days is as easy as pie, and it is quite possible that part of (or most of) the problem is RF interference as opposed to noise on the power line.

Years ago, when I worked at installing two-way radios in police cars, there were numerous problems with a braking module on one particular type of automobile, causing enough radiated RF at about 155 MHz so as to make the radio virtually unusable at low signal levels on a channel in that range. The modules had to be replaced.

My suggestion would be to use an FM radio powered from batteries to determine the source. If it is RF, then the radio being powered by batteries will be just as affected as the one powered by the AC line.

Correction to Answer #9122

The following line "Between C and G there is 24V all the time." should read "Between C and R there is 24V all the time.

Ron Dozier
Wilmington, DE

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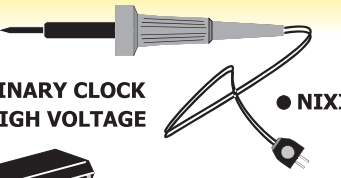

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The best answer in that case may be to try to increase the desired RF signal for the radio with an outside antenna. Replacing the lights or filtering the (probably) electronic ballasts may be quite expensive.

John Greenland
via email

#2 Your noise is probably radiated more than line coupled. Try putting the ferrite chokes on the power lines to the light.

Trapping at the receiver will not suppress the radiated interference! Surge arrestors are not designed to trap noise like this unless they include a noise filter, and then only trap line carried noise.

Len Powell
Finksburg, MD

#3 First, get a battery operated FM radio and test with that. If the noise is still present, it is coming over the air and the only way to stop it is to turn the lights off or replace them with something else that doesn't generate RF hash.

If the portable radio shows no sign of the noise, then it can be licked by more filtering of the AC either coming out of the lights (the best place to put the filters) or at the radio.

I would start — as you did — with the radio side, and try more and different kinds of RF noise filters. Once an acceptable solution is found, I'd do my best to find a way to add these solutions to each light socket to kill the stuff as close to the source as possible.

Digi-Key has all sorts of RF line filters: **www.digikey.com/product-search/en/filters/line-filters/3408328?k=rf%20filters**.

Schurter, Inc., calls theirs EMI/RFI line filters; **www.schurterinc.com/content/view/full/25502/(language)/eng-GB**.

For more, do a search online for "RF AC line filters" or "RFI AC line filters."

MFJ might be another good source since hams don't like EMI or RFI getting into their radios; MFJ-1164B AC line filter, **www.universal-radio.com/catalog/protect/4743.html**.

MFJ usually has a 100% satisfaction return/replacement guarantee for one year, but I didn't see that mentioned for this product.

Phil Karras KE3FL
AEC Carroll County
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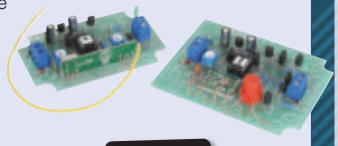

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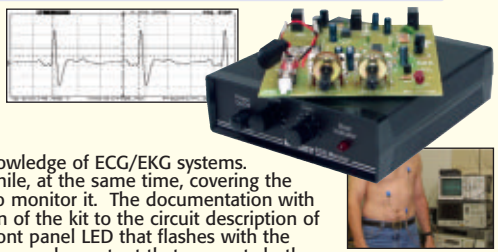

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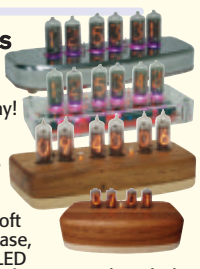

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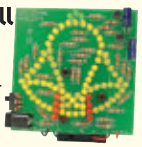

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MK122 **LED Animated Bell Kit** **$16.95**

3D LED Christmas Tree

Not your average LED display! 4 branch sections give this tree a true 3D look! 16 red LEDs light it up with yellow LEDs for you to customize your tree! The base of the tree is actually the 9V battery acting as a self supporting base! Now that's pretty neat!

MK130 **3D LED Christmas Tree Kit** **$7.95**

SMT LED Christmas Tree

Build this subminiature Christmas tree and learn SMT at the same time. Small enough to wear as a badge or pendant! Extra SMT parts are included so you can't go wrong! Runs on Li-Ion cell.

MK142 **SMT LED Christmas Tree Kit** **$10.95**

SMT LED Smiley Face

This is a great attention grabber and also teaches you the basics of SMT construction! Perfect to wear through the holiday season or to hang on your tree as an attention getting ornament! ! Extra parts included! Runs on Li-Ion cell.

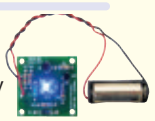
MK141 **SMT LED Smiley Kit Kit** **$9.95**

LED Traffic Signal

Not exactly a holiday theme, a real attention getter for this time of the season! Impress your friends with this neat 4-way traffic signal! Operates just like a standard signal, and features adjustable delay. Red, yellow, and green LEDs are used just like the real thing! Runs on 9V battery.

MK131 **LED Traffic Signal Kit** **$7.95**

LED Switcher Blinkey



Wait, an LED that runs on 3VDC running on 1.5VDC? Learn power supply switching and end up with a super bright Telux LED blinking at 140 kHz! Great to light up your ornaments! Runs on a single standard AA battery (not included).

LSW1 **LED Switcher Blinkey Kit** **$14.95**

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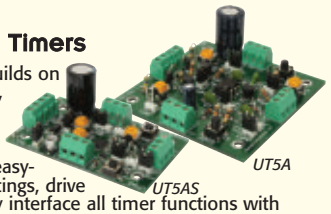
Four-Mode Keyless Entry Test Set

Just like the days of "plugs, points, and condenser" are over, so are the days of having the hardware store grind out a spare key for your car! Now when your keyless access system doesn't work, you need to accurately detect what part of the system is malfunctioning. This could be anything from a dead battery in the key fob, a "brain-dead" key fob, to malfunctioning sensors, antennas, or other system components in the vehicle. Until now there was no way to determine where the system was failing.

Testing your system is easy. To test the complete 125 kHz/315 MHz communications path just stand close to the vehicle with the WCT3 and your key fob in hand. Press the test button and the WCT3 will detect and display the presence of the vehicle's 125kHz/20KHz signal and, if they "handshake", will also detect and display the presence of your key fob's 315MHz return signal. You can independently test key fob only signals (panic, lock, trunk, etc.) by holding the key fob near the WCT3, pressing the test button, and pushing the function button on the key fob. The same functionality testing can be done with IR key fobs. The modulated IR signal is detected and will illuminate the IR test LED on the test set. If you know a few "secrets" you can also see if the tire pressure sensors/transmitters are generating signals or the built-in garage door opener in your rear view mirror is transmitting a signal! Runs on a standard 9V battery. Also available factory assembled & tested.

WCT3 **Four-Mode Keyless Entry Test Set Kit** **$59.95**

Ultimate 555 Timers



This new series builds on the classic UT5 kit, but takes it to a whole new level! You can configure it on the fly with easy-to-use jumper settings, drive relays, and directly interface all timer functions with onboard controls or external signals.

All connections are easily made though terminal blocks. Plus, we've replaced the ceramic capacitor of other timer kits with a Mylar capacitor which keeps your timings stable over a much wider range of voltages! Available in through hole or surface mount versions! Visit www.ramseykits.com for version details.

UT5A **Through Hole 555 Timer/Osc Kit** **$24.95**
UT5AS **SMT 555 Timer/Osc Kit** **$26.95**

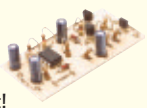
Passive Aircraft Monitor

PATENTED!

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

ABM1 **Passive Aircraft Receiver Kit** **$89.95**

Voice Activated Switch



Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

VS1 **Voice Switch Kit** **$9.95**

OBDII *CarChip Pro*

The incredible OBDII plug-in monitor that has everyone talking! Once plugged into your vehicle it monitors up to 300 hours of trip data, from speed, braking, acceleration, RPM and a whole lot more. Reads and resets your check engine light, and more!

8226 **CarChip Pro OBDII Monitor-Asmb** **$79.00**

RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

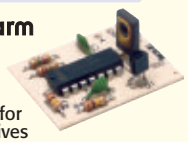
SA7 **RF Preamp Kit** **$19.95**

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.

TS1 **Touch Switch Kit** **$9.95**

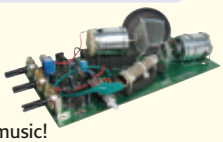
Mad Blaster Warble Alarm



If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

MB1 **Mad Blaster Warble Alarm Kit** **$9.95**

Laser Light Show



Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

LLS1 **Laser Light Show Kit** **$49.95**

Water Sensor Alarm

This little $7 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump)! When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.

MK108 **Water Sensor Alarm Kit** **$6.95**

USB DMX Interface

Control DMX fixtures with your PC via USB! Controls up to 512 DMX channels each with 256 different levels! Uses standard XLR cables. Multiple fixtures can be simply daisy chained. Includes Light Player software for easy control. Runs on USB or 9V power.

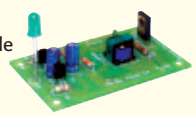
K8062 **USB DMX Interface Controller Kit** **$67.95**

Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

IG7 **Ion Generator Kit** **$64.95**

Tickle-Stick Shocker



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4 **Tickle Stick Kit** **$9.95**

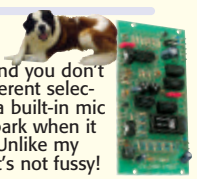
Tri-Field Meter Kit

THE GHOST DETECTOR!

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.

TFM3C **Tri-Field Meter Kit** **$74.95**

Electronic Watch Dog



A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Adjustable sensitivity! Unlike my Saint, eats 2-8VAC or 9-12VDC, it's not fussy!

K2655 **Electronic Watch Dog Kit** **$39.95**

Electret Condenser Mic

This extremely sensitive 3/8" mic has a built-in FET preamplifier! It's a great replacement mic, or a perfect answer to add a mic to your project. Powered by 3-15VDC, and we even include coupling cap and a current limiting resistor! Extremely popular!

MC1 **Mini Electret Condenser Mic Kit** **$3.95**

Sniff-It RF Detector Probe

Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!

RF1 **Sniff-It RF Detector Probe Kit** **$27.95**

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AMFM108K	**AM/FM IC Lab Kit & Course**	**$34.95**

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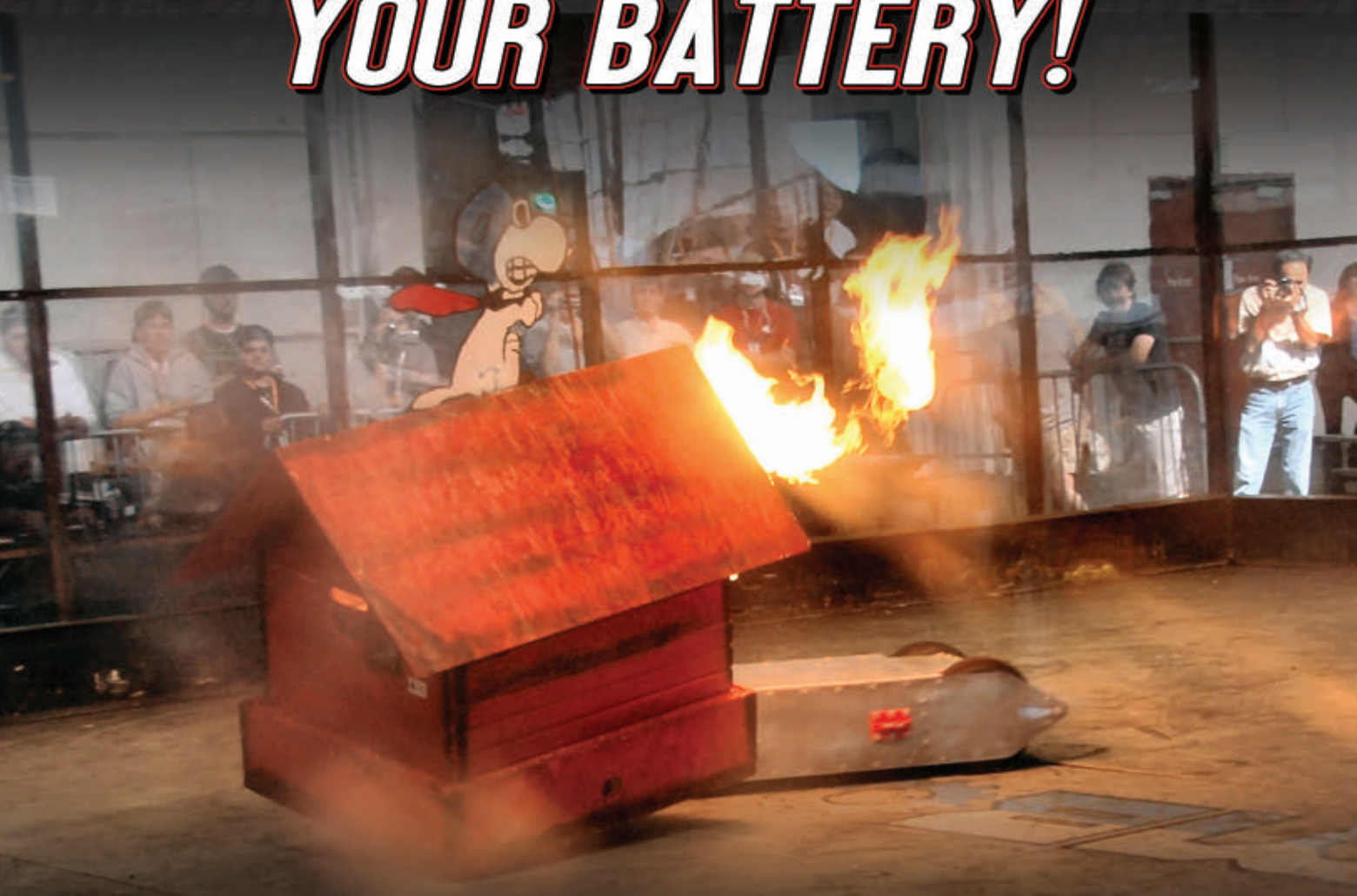

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