PROJECTS THEORY APPLICATIONS CIRCUITS TECHNOLOGY

NUTS AND VOLTS

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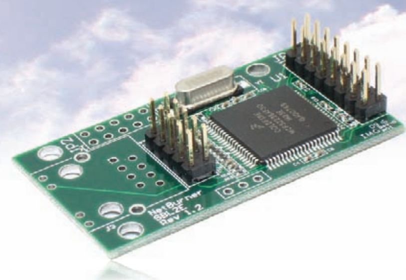

SBL2e 100

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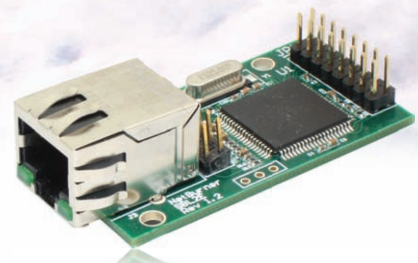

SBL2e

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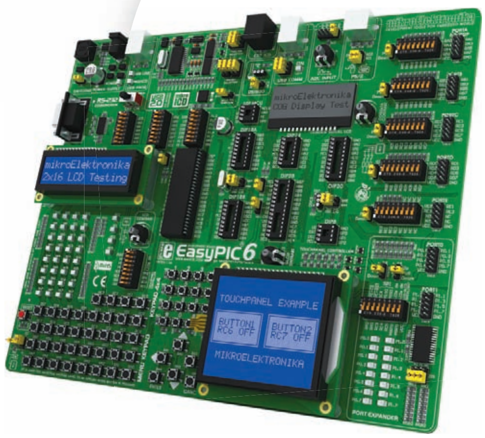

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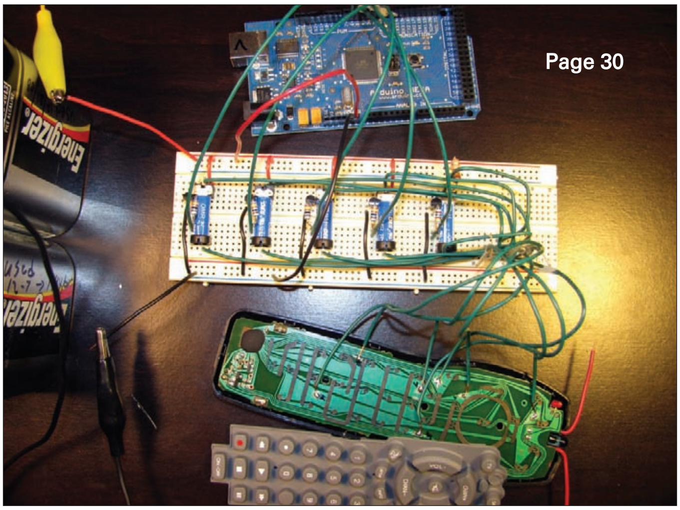

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FUNdamentals For Beginners

Just getting started in electronics? Try these simple demos to illustrate electronics principles and how components function in actual circuits!

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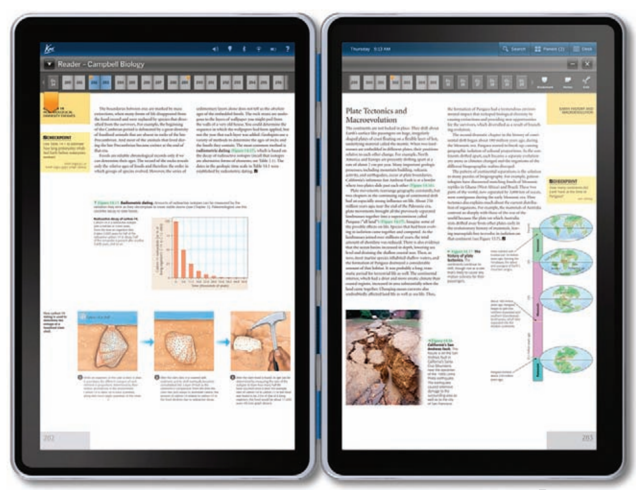

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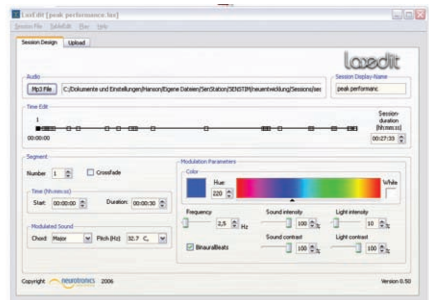

Laxman "Inner-tainment" System NEW!

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Truly in a class all its own, the Laxman 'Innertainment' System is the next generation of mind machines. The revolutionary technology combines the most effective light and sound technology with the features of a state-of-the-art multimedia device. The result is a sensory phenomenon that simultaneously atunes your brain waves to auditory and visual stimulation, creating a ground-breaking display of colorful shapes and a sensation unlike any other.

#31521-51 . . . . $649.00

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This incredibly fun construction kit walks you through building your own motorized vehicles and machines and then control them with a wireless remote control unit. The unique six button infrared remote allows you to control three different motors simultaneously, moving each of them forward or in reverse, with easy-to-activate touch sensors. The three motors can be combined to make complex vehicles and machines in numerous configurations limited only by your imagination. Recommended for Ages 8 and up.

⚠WARNING: CHOKING HAZARD – Small parts. Not for children under 3 yrs.

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Da Vinci Aerial Screw Kit NEW!

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A precursor of the modern day helicopter, the Aerial Screw designed by Leonardo da Vinci was.designed to compress air in order to obtain flight. Now you can build this model straight fromDa Vinci's musings and marvel at how ahead of his time he truly was. Reccomended ages 8 and up.

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DIY Discover Electronics Kit

Everything You Need to Learn Basic Circuit Design NEW!

What are the basic electronic parts? How do they function? How are they related to one another? These questions and more can be answered by spending some time with our electronics kit. It contains over 130 standard parts – all of the most common electronics components, as well as a prototyping breadboard for you to get started on projects right away. Make a light detector, work with IC chips, create an interactive noise maker and more. No soldering required, and the included illustrated manual guides you through each of the projects step-by-step. After you build all of the projects you can use the parts for your own designs too. Recommended for ages 12 and up.

#31522-28 . . . . $49.95

The Swinging Sticks

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Superhero Approved
AS SEEN IN IRON MAN 2

Never ceasing, always swinging, this moving stick model appears to defy gravity and turn logic on its head. The constant, fluid motion of the revolving sticks creates an almost hypnotic effect that your friends, family, and clients will want to watch for hours. The perpetual motion illusion was created by an electrical engineer and designer to baffle and amaze all onlookers. Ideal for conference rooms, medical offices, exhibition areas, waiting rooms, display windows, and foyers, this display provides sophisticated style and unmatched entertainment. Requires 4 AA batteries (not included).

#30850-66 . . . . $289.00

DEVELOPING PERSPECTIVES

Harvesting Power

The increased awareness of climate change and focus on renewable resources has been a boon to the green industry. Fully electric cars — although still expensive and impractical for most of us — are in fashion. Then, there are the wind farms springing up around the US, and talk of wave-powered generators along the east coast. Of course, dams have long been a source of mechanical and electrical power.

Although you may not be able to afford a $100K Tesla Roadster, there are affordable electronic devices that harvest energy from minute vibrations, sunlight, and even water. This last category of technology caught my attention recently as I walked through my local hardware store. Of course, I'm talking about the water-powered LED showerheads and faucet attachments that change color to indicate water temperature. These relatively inexpensive units (starting at $7 on Amazon) power LEDs to indicate cold (blue), warm (green), and hot (red) water. Above a certain temperature, some units also blink red to indicate dangerously hot water.

My teardown of a $12 unit revealed a few LEDs, a thermistor, and — most significantly — a miniature turbine generator. While no match for Hoover Dam, the mainly plastic turbine manages to power a handful of high-output LEDs by extracting energy from the flowing water. The quality of the inexpensive, Chinese-manufactured device isn't impressive, but it is on the market, it's affordable, and it works. That's more than can be said for a lot of green technologies that are 'not quite there yet' economically or technologically. Sidewalks that capture the energy imparted by pedestrians have yet to make it to my community.

My first thought on seeing the miniature water turbine was to identify other practical applications for the device. Could these turbines be wired in parallel and be used to generate power from a river or stream? Or, be placed in gutters as indicators that they're not clogged. Or, used with a water cooler tap to heat or cool water with a Seebeck device — another technology that can be used to reclaim otherwise wasted energy.

The point is, there's a lot of wasted energy in our everyday environment and experimenting with methods of harvesting that energy isn't limited to corporations with deep pockets and teams of researchers. Where can you start? As I've noted in previous editorials, economically, it probably makes sense to start with a teardown of a mass-produced product. If you can afford it, you can try your hand at official product evaluation kits. The advantage of quality evaluation kits is that they provide the documentation and electronic infrastructure to get you up and running in hours instead of days.

Whether it's a turbine generator or one of the new, higher-efficiency solar panels, get your hands on the technology and put your imagination to work. That doesn't mean going it alone in your basement, however. Use the wealth of information in the US and international patent databases, and keep track of new product announcements on the high-tech websites. You can also form a club of like-minded experimenters. Thanks to the Internet, forming a virtual club or special interest group is only a few keystrokes away. Of course, the old-fashioned, face-to-face gatherings are hard to beat, if you have the time and happen to live near like-minded experimenters.

If you're interested in the details of how to extract energy from your plumbing system, take a look at US

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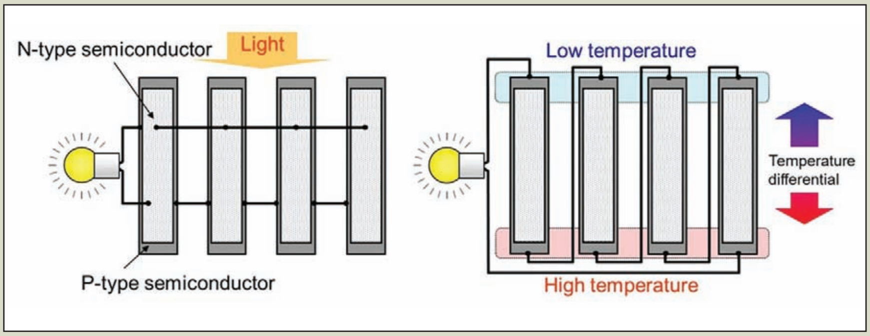
Patent 2007/0037470 A1, "Water-Powered Lighted Toys" on Google's patent site. Consider picking up an inexpensive water-powered shower head on eBay or other online source for teardown material. And, as always, consider sharing your discoveries with your fellow readers here at *Nuts & Volts*. **NV**

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

DEVICE GETS JUICE FROM HEAT AND LIGHT

The idea of deriving electricity from ambient light, heat, vibrations, EM waves, and so on has attracted increased interest over the last few years. However, the amount of power available from such sources is limited as compared to what we can draw from power plants and batteries, and a device that harnesses only one ambient source has a corresponding limit on its output. Therefore, a device that draws off two or more of these simultaneously would have obvious advantages.



■ A single device operates in both photovoltaic (left) and thermoelectric (right) modes.

At the IEEE International Electron Devices Meeting last December, Fujitsu Labs (**jp.fujitsu.com/group/labs/en/**) announced the development of such a hybrid device which can generate electricity from either heat or light. According to Fujitsu, the material is efficient enough to produce power even from indoor lighting (in the photovoltaic mode) and from heat in its thermoelectric mode.

By changing the electrical circuits connecting two types of semiconductor materials (P- and N-type), the device can function as a photovoltaic cell or thermoelectric generator. As a potential application, the company cites sensors that are used to monitor such things as body temperature, blood pressure, pulse, and so on. Such devices could be powered by either light or heat, and if either one is insufficient, one source could be used to augment the other. An added benefit is that it can be manufactured from cheap organic materials, so production costs should remain low. Fujitsu will continue to develop the concept for increased performance and hopes to commercialize the technology by 2015. ▲

DISPOSABLE E-BOOKS?

As you've probably noticed, the price of e-readers has plummeted over the last year or so. A case in point is Amazon's Kindle which hit the market in 2007 at $399 but now is priced at $139 ($189 for the 3G + WiFi version). Now, an engineering researcher at the University of Cincinnati (**www.uc.edu**) has come up with a concept that could make e-readers so cheap that they could be considered disposable. It seems that Prof. Andrew Steckl's research into an affordable, high performance, paper-based display technology has paid off. As described in a recent issue of the American Chemical Society journal *Applied Materials and Interfaces*, the breakthrough is based on using paper as a flexible host material for an electrowetting device. The electrowetting process involves applying an electric field to colored droplets in the display, thereby generating images ranging from simple type to photos and even video.

According to Steckl, "One of the main goals of e-paper is to replicate the look and feel of actual ink on paper. We have, therefore, investigated the use of paper as the perfect substrate for EW devices to accomplish e-paper on paper ... It is pretty exciting. With the right paper, the right process, and the right device fabrication technique, you can get results that are as good as you would get on glass, and our results are good enough for a video-style e-reader."

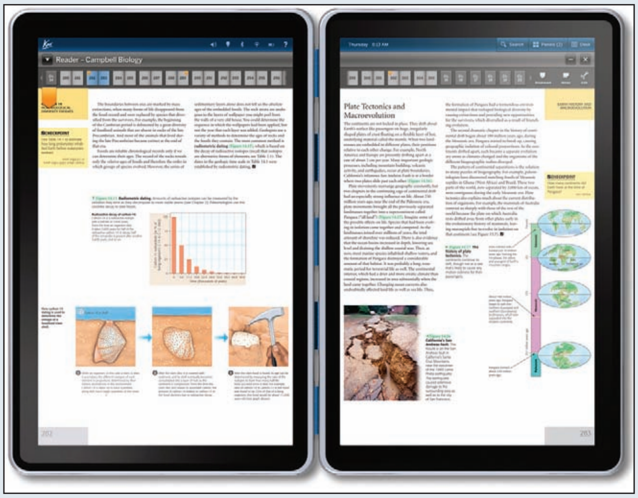
The goal is to achieve a material that can be rolled out like a paper towel, produce even high res color video, and still be tossed when you're done with it. Steckl predicts that it will take three to five years to reach commercialization, so the relatively expensive, glass-based readers will be around for a while. ▲

COMPUTERS AND NETWORKING

TABLET TEXTBOOK INTRODUCED

A company that is bucking the trend toward cheaper e-readers is Kno (**www.kno.com**) which has introduced a device that builds on the e-reader concept by offering a tablet that's designed especially for students. Promising to "revolutionize how you learn," it not only lets you read a book, you can also write notes in the margins, highlight text passages, and browse the Web for doing research.

It comes with a pen stylus that allows for natural handwriting. All of this does come at a price: $599 for a 14.1 inch single-screen tablet and $899 for a dual-screen model.



■ Kno's dual-screen educational tablet, designed for students.

The company emphasizes that — via its arrangements with major publishing houses — students will be able to buy their textbooks for 30 to 50 percent less than the bound versions which over time will offset the cost of the tablet.

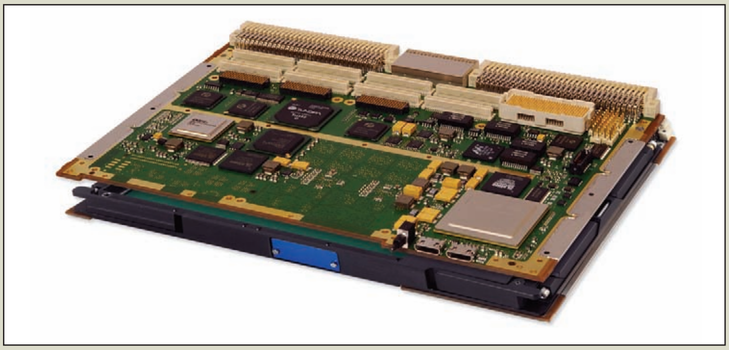
Will the bells and whistles be enough to lure students away from low-end readers? Time will tell. ▲

TAKE A BREAK, WIN A PRIZE

Next time you're insufferably bored at work (say, first thing tomorrow morning), take a break and play "Techtris," the NASA Tech Briefs' online version of Tetris. It's free to play, and the high score of the week wins an unspecified prize from Digi-Key — a major electronic component supplier. Just log onto **www.techbriefs.com/tetris** and test your skill. Maybe you'll win a capacitor or something. ▲

HIGHER PERFORMANCE, SAME POWER CONSUMPTION

Demonstrating in December, GE Intelligent Platforms (**www.ge-ip.com**) brought out the new PPC10A single-board computer, based on the QorIQ™ P4080 eight-core processor from Freescale Semiconductor. According to GE, it provides a significant performance increase over its dual-core PPC9A predecessor but draws no more power.



■ The GE PPC10A single-board computer.

In fact, GE notes that it provides a straightforward, cost-effective upgrade to the PPC9A, and systems that use multiple processor boards can be replaced with a single PPC10A to save space and weight. You can actually get it with either eight or four e500mc cores, each running at 1.5 GHz, and up to 8 GB of dual-channel DDR3 memory.

The machine provides five levels of ruggedization, making it suitable for operation in environments ranging from docile offices to the harsh outdoors. You also get two XMC/PMC sites plus an additional flexible interface extension (AFIX) site for further expansion. GE's AFIX optionally features such capabilities as SCSI, VGA/graphics, a Flash drive, etc. The computer features two (or four) Gigabit Ethernet ports, two (to five) serial ATA ports, two USB 2.0 ports, and 31 GPIO ports. OS support is planned for VxWorks, Wind River Hypervisor, Linus, and the INTEGRITY RTOS. No prices were announced, so you'll have to get a quote from your nearest distributor. ▲

CIRCUITS AND DEVICES

COLLISION AVOIDANCE SYSTEM

■ Mobileye system components: camera, display, and warning buzzer.

As we all know, drivers can be distracted by cell phone calls, text messages, noisy construction work, dripping cheeseburgers, nagging spouses, and a thousand other things, making them dangerous to themselves and others. Take your eyes off the road for even two seconds, and the results can be disastrous. Mobileye (**www.mobileye.com**), however, has introduced an over-the-counter solution: the Mobileye C2-270. The system is a single-camera system for collision prevention, based on the EyeQ2 vision chip. The chip is designed to detect other vehicles, including motorcycles and bicycles, plus pedestrians and even lane markings. The C2-270 consists of three components: a windshield-mounted vision sensor with a compact high dynamic range CMOS camera and image processing board; an alert buzzer; and the EyeWatch2 display and control unit. The smart camera mounted on the inside of the windshield measures the distance (referred to as "headway") to potential obstacles. When the camera detects danger, the display flashes color-coded icons — including the headway distance — and engages a buzzer, providing the driver with up to 2.7 seconds' warning before impact.

All in all, you get four driver assistance applications in one system: (1) pedestrian collision warning; (2) forward collision warning; (3) lane departure warning; and (4) headway monitoring and warning. Until recently, the technology was available only as an integrated feature on some BMW, GM, Volvo, and Nissan models, but now you can add it to your own car for a suggested retail price of $729 plus installation. Sure, that's probably more than that rusted-out old Civic is worth, but we're talking safety here. ▲

■ Intersil's ISL78600, an automotive-grade Li-Ion battery management system, shown with an ISL78601 battery monitor.

BETTER BATTERY MANAGEMENT

Also geared for safety, as well as efficiency in the automotive market, is Intersil's HEV/EV system, consisting of an automotive-grade Li-Ion battery management system and safety monitor. The ISL78600 is designed to address safety, reliability, and performance considerations for hybrid, plug-in hybrid, and pure electric vehicles. In terms of safety, the system provides ISO 26262 standard compliance to prevent battery pack failures, plus fault detection for internal functions, as well as external faults such as open wires, overvoltage, undervoltage, temperature, and cell balance faults. Each device utilizes a 14-bit temperature-compensated data converter that scans 12 channels in less than 250 microseconds.

Average mid-size HEV vehicles today use 126 to 168 cells, so designers will need to include 11 to 14 chips per vehicle. When combined with four external temperature sensors, the ISL78600 provides state-of-charge measurements across the full battery operating temperature range. The unit can be connected to microcontrollers via either a 2.5 MHz SPI or 400 kHz I²C interface, and is specified for -40 to 105°C operation. It will run you about $6.50 in manufacturing quantities. ▲

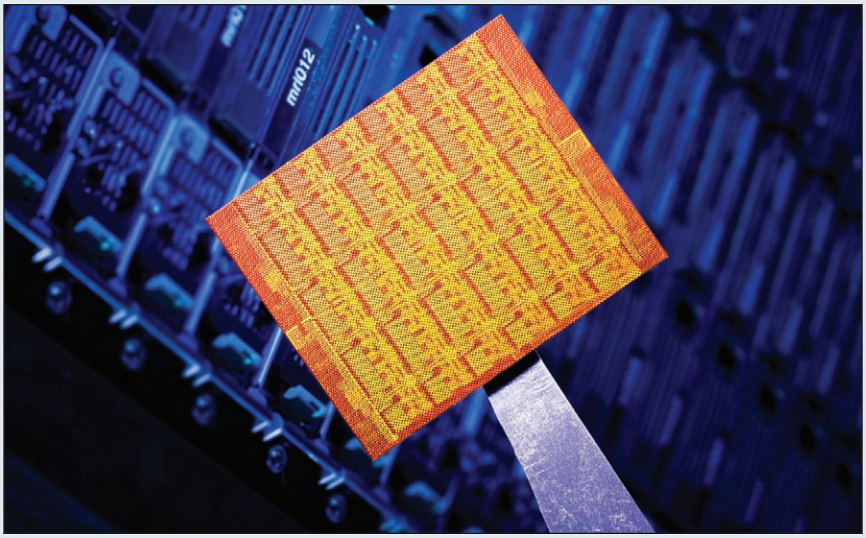
MAJOR UPGRADE FOR SPEAKERPHONES

■ Wolfson's WM8958 audio hub.

If you have ever tried engaging the speakerphone function on your cell, you will be fully aware of the tinny, almost inaudible sound that results. However, Wolfson Microelectronics (**www.wolfsonmicro.com**) is aiming to fix that courtesy of its WM8958 audio hub, a low power codec designed to provide high definition, teleconference-quality sound to phones as well as tablet computers, e-books, satellite navigation systems, and other portable appliances. The three-channel audio hub provides 100 dB s/n during digital-to-analog playback while its integrated stereo class S/AB speaker driver and Class W headphone driver reduce playback power consumption. An audio enhancement DSP runs a three-band compressor to improve the sound from small speakers. Used with an on-board parametric equalizer and dynamic range controller, the compressor can boost and optimize speaker outputs to improve audio playback quality. A smart digital microphone interface provides power regulation, a low jitter clock, and decimation filters for up to four digital microphones. Active ground loop noise rejection and DC offset correction help to eliminate pops and suppress ground noise on the headphone output. According to Wolfson, the product is sampling now and will be ready for production early this year. Products incorporating the WM8958 should begin appearing in the third quarter. ▲

INDUSTRY AND THE PROFESSION

EXASCALE INSTITUTE FORMED



■ An Intel high-core-count experimental chip that could provide a path to exascale computing.

While the US and China battle it out in the teraflop computing realm, the Department of Energy's Argonne National Laboratory is looking a bit farther into the future. ANL has created the Exascale Technology and Computing Institute (ETCi), headed up by renowned supercomputing guru Pete Beckman, former director of the Argonne Leadership Computing Facility.

The focus is on creating the next generation of supercomputers that will be 1,000 times more powerful than China's Tianhe-1A, currently Numero Uno in the world. Exascale machine performance will be measured in exaflops which are the equivalent of a quintillion floating point operations per second. Yep, that's 1,000,000,000,000,000,000. One million trillion. Four hundred million times the number of burgers McDonald's has sold. Fifty nine times the number of gallons of water in the Atlantic Ocean. Pretty close to what the national debt will be in a few years. The mind boggles.

"Supercomputing architectures are rapidly changing," Beckman observed. "New technology will necessitate transforming system software and applications to enable new scientific discovery at extreme scales. By using principles of co-design, computer scientists and applied mathematicians, industrial partners, and the scientists using today's supercomputers can work together to make exascale computing a reality."

Over the next 10 years, the community will work together to simultaneously address a number of daunting technical challenges, such as developing ultra-low power designs, 3-D chip configurations, massively parallel programming models, silicon photonics, and hybrid multicore architectures. ▲

■ BY RON HACKETT

EXPERIMENTING WITH TOUCH-SENSITIVE KEYPADS

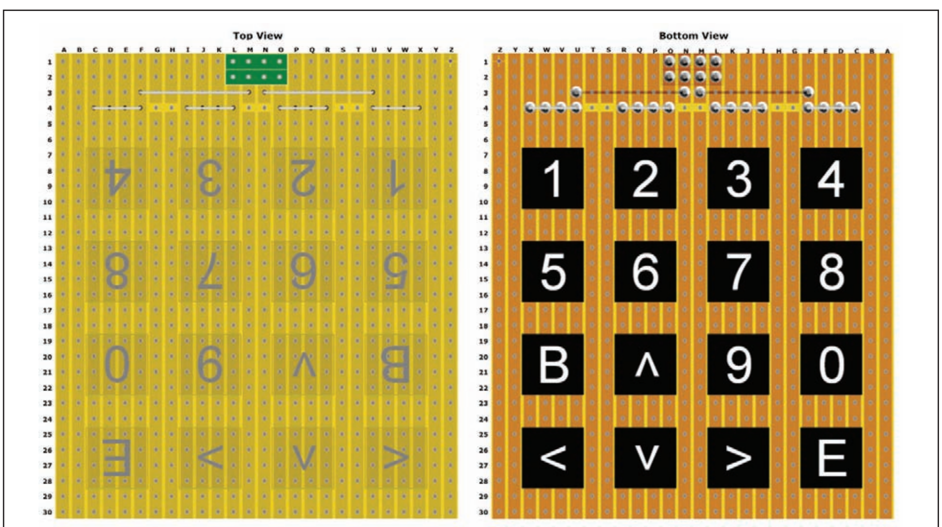
In this month's installment of the Primer, we're going to explore two different implementations of a touch-sensitive keypad. However, before we get started, I want to mention a recent announcement from Revolution Education. Updated versions of the PICAXE-28X2 and 40X2 processors are now available (as of December '10). The two new processors now support both 3V and 5V operation. In other words, the updated processors can operate anywhere between 2.1V and 5.5V. In addition, both processors include many additional ADC inputs, as well as support for capacitive touch inputs similar to those of the 18M2 processor. If you are interested in the details, an updated datasheet for the X2 parts is available on the Revolution Education website (www.rev-ed.co.uk/docs/picaxex2.pdf).

CONSTRUCTING A STRIPBOARD MATRIX TOUCHPAD

Naturally, my first approach to constructing a matrix keypad involved the use of stripboards. Building the keypad was easier than I thought it would be, but, as we will soon see, I haven't been able to obtain reliable readings from the touch inputs. However, I did learn a considerable amount about touch inputs in the process, so I think it's been a worthwhile endeavor.

In case you feel you have sufficient frustration tolerance to work with unreliable input readings, I'll explain how I built the keypad so you can conduct your own experiments with stripboards. (If you have more success than I did, I would love to hear about it.) If you would rather not get involved in a potentially frustrating endeavor, later on I'll describe a printed circuit board (PCB) approach to touch-sensitive keypads that completely resolves the issues I had with my stripboard keypad.

My design for a matrix touchpad employed two identical stripboards in a "sandwich" arrangement to essentially duplicate a standard 4x4 matrix keypad. In other words, I constructed a two-board sandwich that had four rows and four columns, and required eight touch inputs for interfacing with the 18M2 processor. **Figure 1** shows the LochMaster layout for the top stripboard in the sandwich. (A larger version is also available for downloading from the *N&V* website.) As you can see, the key layout is shown correctly on the bottom of the board (not the top). That's because I used the board upside-down – I wanted to keep the copper traces as close to the surface



■ FIGURE 1. Stripboard layout for a 4x4 matrix touchpad.

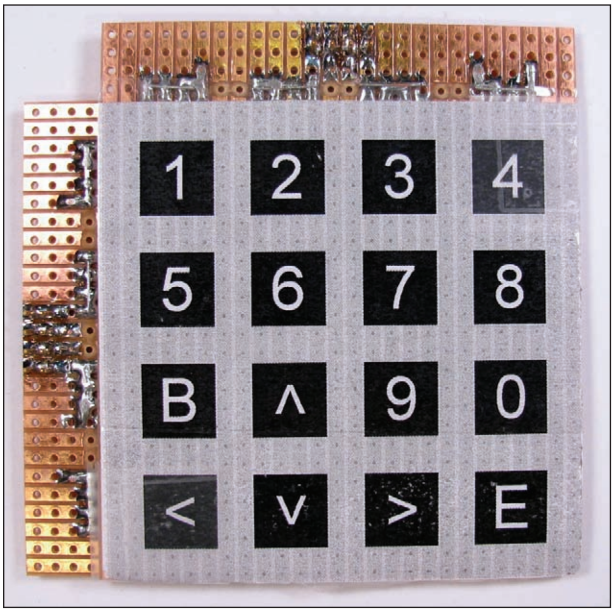
as possible. (In the top view, LochMaster has rotated the key labels 180 degrees for some strange reason; just ignore that!) The construction of the second stripboard in the sandwich is identical to the first one. Of course, there's no need to add key labels to it.

The key arrangement on the touchpad is one that I have used before. The "B" key is intended to be used as a "Back" button, the "E" key is "Enter," and the four arrow keys are for cursor movements (left, right, up, and down). Even though the 10 digits are in a somewhat non-standard arrangement, the layout works well for me; mainly because the four arrow keys are spaced correctly, and Enter is in the lower right corner where it belongs. Of course, you can easily redefine the key layout in software if you prefer a different arrangement.

The reason for the double-row header at the top of the stripboard is that I like to use ribbon cable assemblies for connections like this. If you also use this approach, you will need to use male headers with slightly longer pins so they can be reverse-mounted. This is because in the final assembly, both boards will be used with their bottom sides facing up. If you prefer, you can use female headers on the stripboards, and just connect jumper wires to your breadboard. In that case, single-row headers would be sufficient. Of course, you can also skip the headers altogether, solder jumper wires directly to the stripboards, and just plug the other ends of the jumper wires into the breadboard.

As I have already mentioned, the construction of the two stripboards is identical, and the layout is simple enough to not require a formal schematic. Essentially, each column (and row) consists of four traces that are electrically connected to one (or two, for ribbon cables) pin(s) on the header. Similarly to our previous touch sensor experiments, the two traces between each column (or row) just spread out the keys to make them easier to press reliably.

In my first attempt at soldering the boards, I tried to solder short bare jumpers on the bottom of the board at the appropriate locations in row 4 of the layout shown earlier in **Figure 1**. However, even with a small spring clamp holding it in place, a jumper would frequently slide out of position as I tried to solder it which was very frustrating! It finally dawned on me that it would be easier to insert a 0.3 inch jumper wire (with excess length on one end) from the top of the board into the ends of each set of four holes, and then bend the excess lead back to the other end of the jumper on the bottom of the board. The jumpers were quick and easy to install using this approach; just be sure to solder the lead on the bottom of the board to all four traces.



■ FIGURE 2. Assembled 4x4 matrix touchpad.

When both boards are completed, refer to **Figure 2** to assemble the sandwich. The bottom board — which is used for the row inputs — is oriented so that its header is on the left with the bottom of the board facing up. It's difficult to see in the photograph, but the header pins are protruding from the trace-side of both boards, so a ribbon cable can easily be attached to each board.

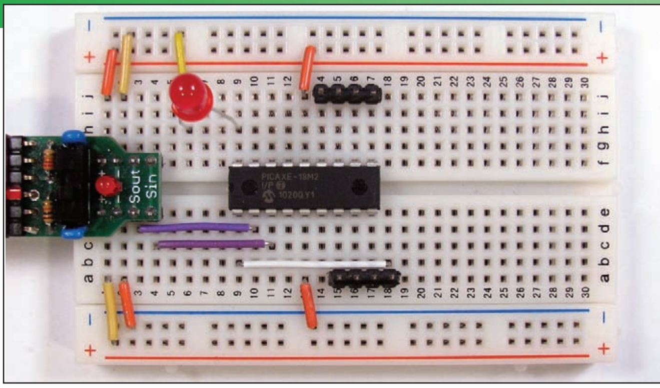
The top board — which is used for the column inputs — is placed on top of the bottom board (again, with its bottom side facing up) so that its header is at the top. The two boards are aligned so that their bottom and right edges line up. On top of the "column" board, I placed a paper template for the key layout (actually, a full-size printout of the LochMaster layout), trimmed it to fit, and then taped the entire assembly together with transparent packing tape.

In addition to identifying the key locations, the label and tape also serve to insulate the traces from direct contact by a finger. Because the PICAXE touch inputs actually measure capacitance, it's important to always insulate touch sensors from the possibility of direct contact.

As soon as my keypad was completed, I set up a simple 18M2 breadboard circuit to test it. **Figure 3** shows the pin connections I used for the two headers. I chose this specific pin arrangement to make the breadboard connections as simple as possible. On one side of the 18M2, pins B.4 through B.7 are all touch inputs (see the 18M2 pin-out from the previous Primer column); I connected those inputs to the "column" header pins. On the other side of the 18M2, there are only three contiguous touch inputs, so I ran a jumper wire from pin C.2 (the only other touch input on that side of the chip) down to one position below

Matrix Pin	I/O Pin
Column 1	B.5
Column 2	B.4
Column 3	B.7
Column 4	B.6
Row 1	B.3
Row 2	C.2
Row 3	B.1
Row 4	B.2

■ FIGURE 3. I/O pin connections for row and column inputs.



■ FIGURE 4. Breadboard setup before connecting the touchpad.

pin B.3 which gave me four touch inputs in a row on that side also.

Figure 4 is a photo of my final breadboard setup for the stripboard touchpad, before I connected the two ribbon cable assemblies. In it, you can see the two four-pin, double-ended male headers into which the ribbon cables will be inserted. If you use this approach, don't forget to make sure that you are using the same four out of five positions on both ends of each ribbon cable. The simplest way to do this is to align the first pin of each male header with the first position on each end of the cable (marked with the red stripe), as shown in the photo of the complete breadboard setup in **Figure 5**.

TESTING THE COMPLETED MATRIX TOUCHPAD

Last time, we worked with the 18M2's *touch* command. Similarly to the PICAXE ADC commands, there are actually two different touch commands: *touch* and *touch16*. As you might suspect, *touch* uses an eight-bit variable, while *touch16* uses a 16-bit variable which gives it more precision of measurement. In addition, *touch16* also includes an optional configuration byte that can be used to "fine tune" the operation of the *touch16* command when necessary. (For details, see the documentation for the *touch16* command in Section 2 of the PICAXE manual).

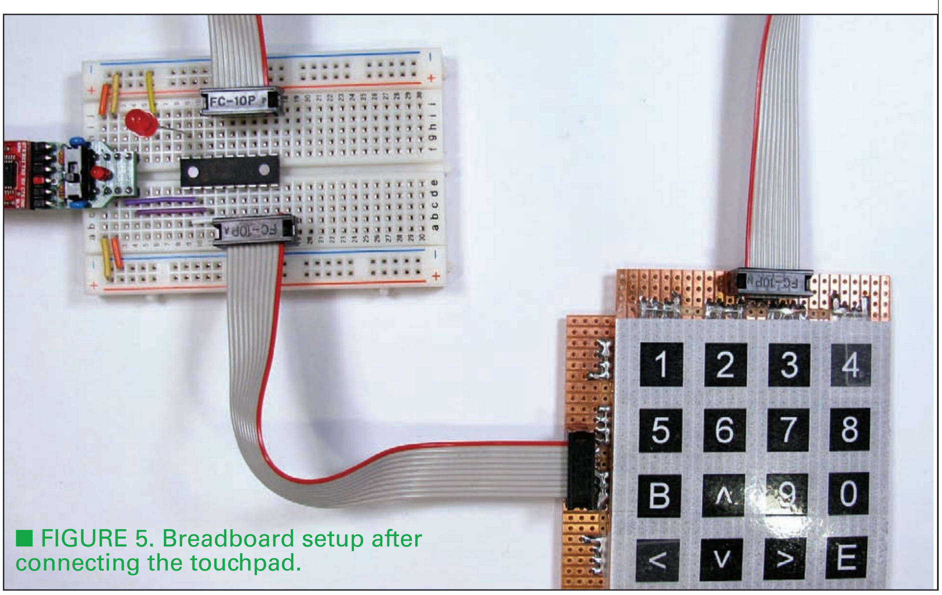
For my first test of the stripboard keypad, I used the *touch* command to simply measure the values for the eight touch inputs that we are using, and sent them to the terminal window for viewing. I was disappointed when I couldn't find any reliable differences in the touch measurements, no matter which key I pressed. This was especially true for the row inputs. Of course, that isn't surprising, since those inputs are connected to the bottom stripboard which means that the row traces (as compared to the column traces) are further away from my finger whenever I touch a key.

Hoping to improve the situation, I switched to the *touch16* command which was, in fact, somewhat better. Using it, I could reliably detect which column was being pressed, but the row measurements were still unreliable. In addition, my software frequently failed to detect a touch input at all if I pressed the key a little too quickly. I spent several frustrating hours trying various adjustments in the *touch16* command's configuration byte, including several attempts that defined two different configuration bytes for the row and column inputs to see if I could improve the reliability of the row measurements using that approach.

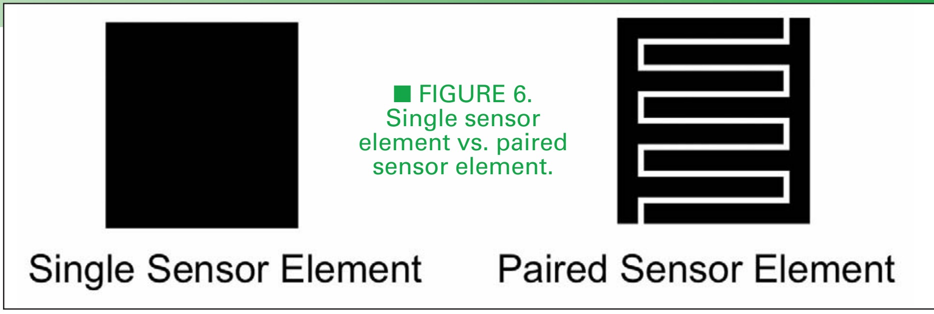
However, I was never able to reliably detect which row was being pressed. I did learn a fair amount about the configuration byte, though. Most importantly, I was able to speed up the touch measurements sufficiently enough to eliminate the problem of quick key-presses being undetected by the software. Changing bits 7-5 of the configuration byte from the default of "000" to "111" easily corrected the problem. If you want to explore these issues on your own, the last test program that I worked with (*TouchMatrixTest.bas*) is available in the downloads.

A LITTLE THEORY

In addition to experimenting with stripboard-based touch inputs, I have also done some web-based research on the topic of designing a PCB version of a touch-sensitive keypad. I didn't find much useful information until I read a message on the PICAXE forum that mentioned an Application Note (AN1104) published by Microchip Technology, and titled *Capacitive Multibutton Configurations*. (This is just one more example of how valuable the PICAXE forum can be. If you aren't already a member, it's well worth joining!) If you're interested in reading this application note, go to the Microchip website (**www.microchip.com**) and search for "AN1104."



■ FIGURE 5. Breadboard setup after connecting the touchpad.



■ FIGURE 6. Single sensor element vs. paired sensor element.

The most valuable piece of information that I learned from reading AN1104 was just how limiting a "matrix mindset" can be when implementing touch inputs. For example, I have always assumed that you need eight input pins in order to implement a keypad with 16 keys (four columns and four rows, of course). However, AN1104 clearly explains how it's possible to scan as many as 21 touch inputs using only six input pins. Even more amazing — at least to me — is the fact that eight input pins can scan up to 36 touch inputs!

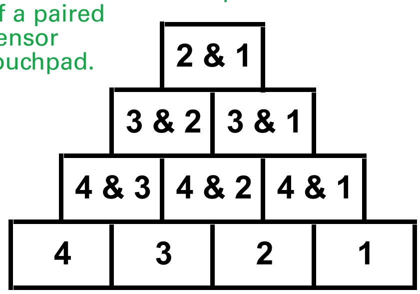
It's all accomplished by designing the touch input pads on a PCB in such a way that they become what are called *paired sensor elements*. **Figure 6** (adapted from **Figure 4** in AN1104) shows a traditional *single sensor element* on the left side; it's simply a rectangular copper area that that can be connected to a single input pin and used as a touch sensor. The element on the right is called a *paired sensor element* because each of its two (separate) copper areas can be connected to a different input pin. Whenever a finger touches the (insulated) surface of a paired sensor element, touch values of two different touch inputs are affected.

As a simple example of how these two types of sensing elements can be combined, let's consider how many sensors we can implement using only four input pins. First, each pin can be directly connected to its own single sensor element (that's four sensors so far). Also, each input pin can be connected to three different paired sensor elements, each of which is connected to one of the remaining three input pins. At first glance, you might think that would be 4*3 or 12 additional sensors, but it's actually half that number. For example, connecting pin 2 and pin 3 to one paired sensor element is the same as connecting pin 3 and pin 2 to a second paired sensor element. In order to eliminate all those duplications, we need to divide by two. Therefore, four input pins can be connected to four single sensor elements, and (4*3)/2 or six paired sensor elements for a total of 10 sensors.

If any of that isn't clear, take a look at **Figure 7** which presents the same information visually. The bottom row of **Figure 7** displays the four single sensor elements. The next row up shows the three possible paired sensors that include input 4. The third row from the bottom shows the two possible paired sensors that include input 3. (Don't forget, the 4 and 3 combination has already been accounted for in the previous row.) Finally, the top row contains the one remaining paired sensor combination that includes input 2. (Again, the other two possible combinations for input 2 have already been accounted for.) So, that gives us a total of 10 sensors for four touch inputs. Of course, on a PCB the keys aren't restricted to the triangular arrangement of **Figure 7**; they can be placed in any arrangement you want — even a matrix!

In general, N input pins can be connected to N*(N-1)/2 + N sensors. If you do a little algebraic simplification, that formula is equivalent to N*(N+1)/2; so, with four touch input pins, we again arrive at 4*(5)/2 = 10 sensors. (And you thought algebra was boring!) If you do the math, you will see how six input pins can be used to scan as many as 21 touch sensors.

■ FIGURE 7. Visual representation of a paired sensor touchpad.



If you don't like doing math (or algebra), you can refer to **Figure 8** which presents the maximum number of sensors vs. the number of touch input pins (from 2 to 10). As you can see, the 10 touch inputs on the 18M2 make it theoretically possible for the chip to interface with 55 touch sensors. (However, you might have to hold your finger on a touch sensor a little longer than usual to give the chip enough time to process all that data!)

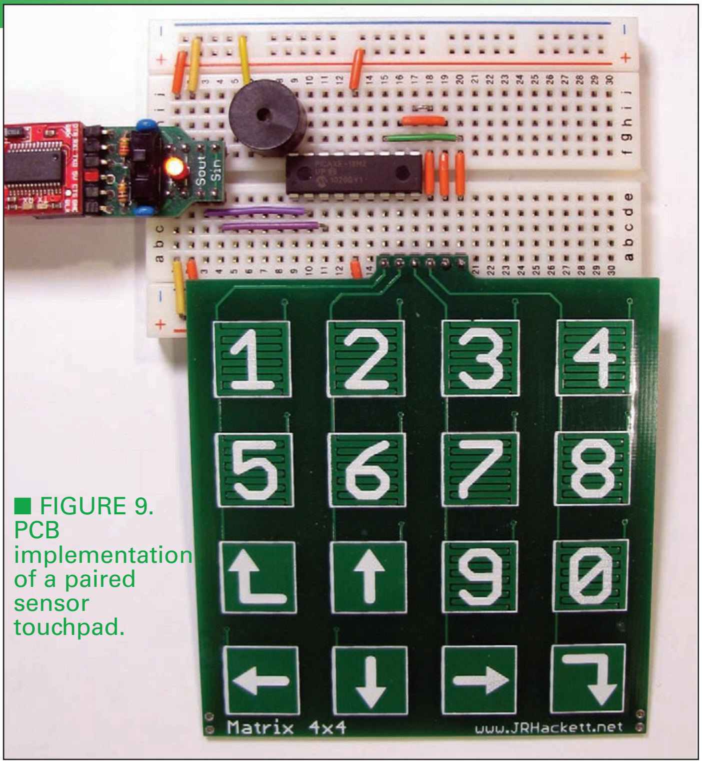
PCBS TO THE RESCUE!

A couple of months ago, I decided to use the information discussed in AN1104 to design a PCB for use as a touch-sensitive keypad. **Figure 9** is a photo of my first prototype PCB installed in an 18M2 breadboard circuit. (The piezo provides an audible key-click for each key-press.) Because of the rectangular key layout, it may look like a matrix keypad, but it isn't – I have seen the light, and I am free!

As you can see, the PCB uses the same key arrangement as my frustrating stripboard version. In this

■ FIGURE 8. Maximum number of sensors vs. number of touch input pins.

Inputs	Sensors
2	3
3	6
4	10
5	15
6	21
7	28
8	36
9	45
10	55
N	N*(N+1)/2



■ FIGURE 9. PCB implementation of a paired sensor touchpad.

case, however, I made up my own symbols for the *Back* and *Enter* keys. Also, you can clearly see the paired sensor elements that I used for the 10 digit keys and the single sensor elements that I used for the six remaining keys. Of course, we now know that I could have included five more sensors for my six-pin interface, but I wanted to keep it simple for my first attempt.

Fortunately, there was absolutely no frustration involved in testing this version of a touch-sensitive keypad. It consistently functions well, and can reliably detect and discriminate which key has been pressed — probably because all the sensor areas are on the top of the board. Also, because it only uses six touch inputs, it's faster than the stripboard version, so reasonably quick key-presses are always detected. However, I still want to modify the PCB slightly, and have another prototype produced for testing. As you can see, the PCB covers the power rails on the bottom edge of the breadboard which turns out to be more inconvenient than I thought it would. Also, the keypad wobbles a little when pressed vigorously. For both those reasons, I plan to redesign the way the keypad connects to the breadboard.

When I have tested the modified prototype board, I'll have the keypad produced in quantity and add it to the PCBs that are currently listed on my website. I hope to have the final PCBs available shortly after this issue is published. (However, I have never been known for the accuracy of my time predictions, so check my site periodically if you are interested in the touch-sensitive keypad.) I will also include the program that I used to decode the keypad, but in case you're interested in seeing what's involved in the decoding process, the software that I used (*TouchPairedDecode.bas*) is also available for downloading at the *N&V* website.

MORE TO COME ...

As I mentioned last time, we aren't finished with the 18M2's touch inputs yet. In the next installment, we'll experiment with the possibility of using touch sensors to detect the presence of water or other liquids, and/or to measure the level of a fluid in a non-metallic tank. As you already know, I would like to develop a simple means of measuring the level of water in the tank of my espresso machine. In addition, I'm sure you can come up with useful applications of your own for a simple and reliable water-sensing device.

When we have finished our exploration of the touch inputs on PICAXE processors, we'll move on to some of the other new 18M2 features. I especially want to take a look at the 18M2's "multi-tasking" capabilities. See you next time ... **NV**

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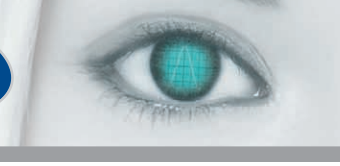

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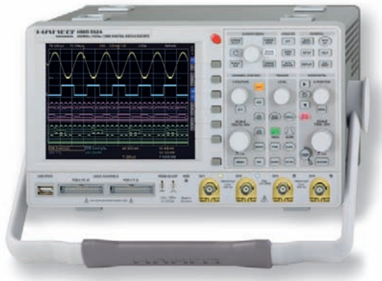

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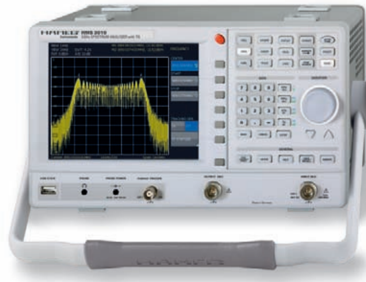

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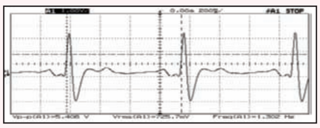

The documentation with the ECG1C covers everything from the circuit description of the kit to the circuit description of the heart! Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hook-ups. In addition, a monitor output is provided to connect to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see in a real ER or on one of the medical TV shows! See the display above? That's one of our engineers, hooked up to the ECG1C after an engineering meeting! (We were all surprised it wasn't flat lined!)

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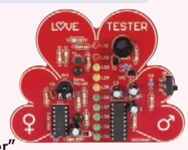

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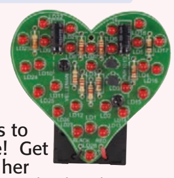


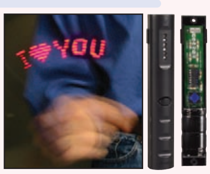
What a way to display your feelings to that very special person in your life! Get out your soldering iron and dazzle her with this unique dual heart electronic display that you can say you built yourself!

28 brilliant red LEDs are formed into two separate heart designs on the heart shaped PC board creating a great flashing display that's easy to assemble. Built-in battery holder base makes the sweetheart freestanding and perfect for a desk or table. Runs on a standard 9V battery (not included). Measures 2.4" x 2.4" x 1.2".

MK101	**LED Flashing Sweetheart Kit**	**$6.95**

LED Magic Wand

- ✔ Message floats in air!
- ✔ Fun at concerts & events!
- ✔ High visibility red LEDs
- ✔ Pre-programmed or custom messages

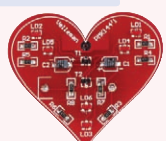


Use the "Magic Wand" to display your true feelings! Simply shake it back and forth and brilliant messages seem to appear in mid-air! Six high intensity LEDs are microprocessor controlled to display messages and graphics that are pre-programmed into the wand. You can also custom program a message of your choice! From amazing your friends, making a statement at a concert, or simply telling your loved one how you feel, the message wand can't be beat! Runs on two AAA batteries (not included), and features auto power-off.

MK155	**LED Magic Wand Kit**	**$12.95**

SMT LED Heart Display

- ✔ Alternating flashing!
- ✔ 6 super bright SMT LEDs!
- ✔ Learn all about SMT!
- ✔ Definitely gets her attention!



This cute little kit gives you a distinctive red display using 6 Surface Mount (SMT) LEDs. The PC board is in the shape of a red heart. The small size makes it perfect to be used as a badge or hanging pendant around your neck. Even better as an illuminated attention-getting heart to accompany a Valentines Day card! Makes a great SMT learning kit to bring you into the world of SMT technology, design, and hands-on soldering and troubleshooting. Don't worry, extra SMT parts are included just in case you lose or damage any! Runs on a small CR2025/32button cell (not included). Measures 1.9" x 1.7" x .3".

MK144	**SMT Flashing Heart Kit**	**$11.95**

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- ✔ 130, 200, 300, & 500 in one electronic labs!
- ✔ Practical through hole and SMT soldering labs!
- ✔ Integrated circuit AM/FM radio lab!
- ✔ Fuel Cell, Solar Hydrogen, and Bio-Energy labs!
- ✔ Beginner's non-soldering kits!

For over 3 decades we've become famous for making electronics fun, while at the same time making it a great learning experience. As technology has changed over these years, we have continued that goal!

PL130A Gives you 130 different electronic projects together with a comprehensive learning manual describing the theory behind all the projects.

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PL300 Jump up to 300 separate projects that start walking you through the learning phase of digital electronics.

PL500 The ultimate electronics lab that includes 500 separate projects that cover it all, from the basics all the way to digital programming.

SP3B Whether young or old, there's always a need to hone your soldering skills. Either learn from scratch or consider it a refresher, and end up with a neat little project when you're done!

SM200K Move up to Surface Mount Technology (SMT) soldering, and learn exactly how to solder those tiny little components to a board!

AMFM108K We not only take you through AM and FM radio theory but we guide you through IC's. When you're done you've built yourself an IC based AM/FM radio that works great!

KNS10 With a reversible PEM fuel cell that combines electrolysis and power conversion into a single device you end up building your own fuel cell car! Learn tomorrows technology today!

KNS11 Learn alternative fuel technology while you build your own H-Racer car and refueling station!

KNS13 Convert ethanol alcohol to run a PEM fuel cell and watch it all work in front of your eyes!

KNS1 A great beginner's kit for the dinosaur enthusiast in the family, young and old! A wooden hobby kit that teaches motor and gear driven operation that requires no soldering.

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PL200	**200-In-One Lab Kit**	**$69.95**
PL300	**300-In-One Lab Kit**	**$89.95**
PL500	**500-In-One Lab Kit**	**$219.95**
SP1A	**Through Hole Soldering Lab**	**$9.95**
SM200K	**SMT Practical Soldering Lab**	**$22.95**
AMFM108K	**AM/FM IC Lab Kit & Course**	**$34.95**
KNS10	**Fuel Cell Car Science Kit**	**$82.95**
KNS11	**H-Racer & Refueling Station Kit**	**$144.95**
KNS13	**Bio-Energy Fuel Cell Kit**	**$129.95**
KNS1	**Tyrannomech Motorized Kit**	**$17.95**

Q&A

■ WITH RUSSELL KINCAID

In this column, I answer 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**

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

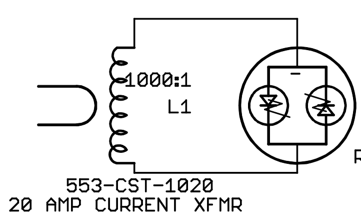
- ✔ CAT 5 Cable Tester Revisited
- ✔ 400 Hz Gyro Drive
- ✔ LED Chaser Circuit

A CURRENT INDICATOR CIRCUIT

Q I have a new spa that has an automatic maintenance cycle; it runs every 12 hours. It is powered from a 208V three-wire 30 amp circuit. I would like a simple LED indicator in the house to tell me it is running or that I left it running after using it. I was thinking in terms of something starting with a small toroid with a few turns on it to slip over the red or black hot lead with a completely floating sensor circuit running off a couple of AA cells. Suggestions would be appreciated.

— Bill Hosking

A I believe that you will find the spa draws about 10 amps when running; more at startup. All that is needed is a current transformer and back-to-back LEDs for a load. The LED shown in the schematic in **Figure 1** is a dual red/green which will probably look yellow because of the color mixing. The part numbers are Mouser; current transformer: $6.11, LED: $0.20.



■ FIGURE 1

CAT 5 CABLE TESTER

Q I do quite a bit of CAT-5/6 cable installations for telephone and data networks. Although I teach my crew to be very careful when attaching a RJ-45 plug or jack, invariably we end up with a few cables with crossed, open, or shorted circuits.

There are quite a number of LAN/telephone circuit testers on the market which are able to identify which pair or wire is shorted, crossed, or open, but the biggest problem and time waster is knowing which "end" needs to be fixed. One of Murphy's Laws states that we will spend 20 minutes going to and inspecting the wrong end. Sometimes it's so difficult to ID the conductor colors in a plug that we end up cutting off and reconnecting both ends. Sometimes the mistake even gets repeated.

No one seems to make a tester that can ID which end of the cable needs fixing. It seems to me that a circuit tester with a little more processing power and smarts could also determine if, say, wire 1 is on pin 1 at end "A" but on pin 2 at end "B."

Yes, there are considerations for "cross-over" and data "A"/"B" circuit connections, but most good technicians know how to keep that in perspective for the type of circuit being connected and tested.

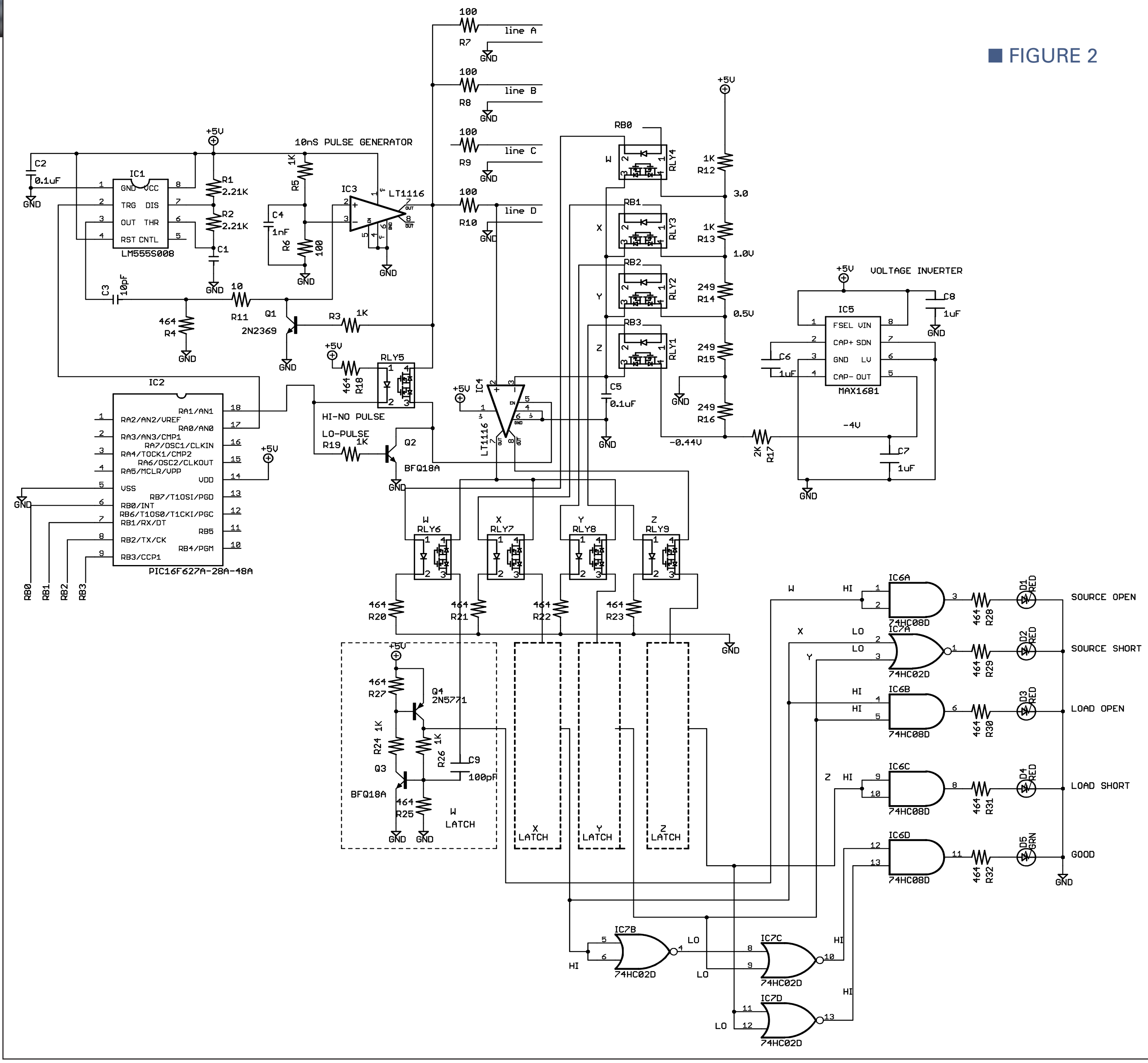
A CAT-5/6 cable tester to ID the miswired end would sure be welcomed and a very worthwhile project to build. Any help would be greatly appreciated.

— Vonn Hockenberger

A As I said in January, a time delay reflectometer is needed. I won't have time to do a complete design, but I will show a partial schematic and explanation of how it should work; see **Figure 2**.

The CAT5 cable is specified to be no more than 100 meters long and the nominal time delay is 5 nS per meter, so the round trip time delay is about one microsecond, worst case. When a pulse is applied to the properly terminated line, it travels down the line and is absorbed by the load; there is no reflection. If the line is open circuit, the current has no place to go and produces a high voltage at the end. As the voltage collapses, a current is sent back to the transmitter. If the transmit end is properly terminated, the pulse is reproduced minus losses.

It is convenient to have a short pulse otherwise it is necessary to differentiate between the normal pulse height and the extra high pulse that occurs when the reflection comes back. With a short pulse (10 or 20 nS), it is only necessary to see if there is a pulse after the main pulse (for an open circuit).



■ FIGURE 2

When the line is shorted or loaded with less than the characteristic impedance, a large current occurs at the load end which flows back to the source. Since this current is in the reverse direction, it produces a negative voltage at the transmit end. If the time delay is less than the pulse width, the return pulse subtracts from the input and will go negative when the input pulse ends.

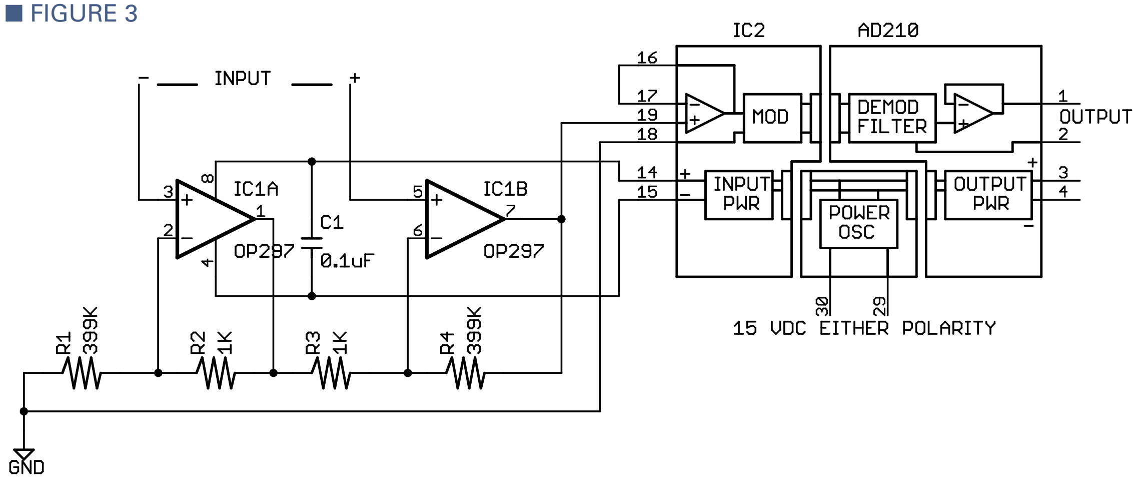
A miswired cable can appear open or shorted depending on how it is miswired. If wires of different pairs are paired, the characteristic impedance will be higher than normal (I think); so, the 100 ohm load will be too small and a negative return pulse will happen. If the miswiring is such that the test does not ground one side of the line, it will appear open and a positive pulse will happen. In these cases, you cannot tell which end has the error.

Figure 2 is the schematic. The block labeled SSR is a low resistance solid-state relay. Because the SSR switching is slow, the controller will have to initiate a new pulse each time a change is made.

The way this circuit (**Figure 3**) is supposed to work is a pulse is sent down the cable to the load where it is absorbed. There is no reflection in that case and the cable is good. If there is no load or the load is higher than the cable impedance, a positive pulse travels back up the line and is detected by a comparator which sets an error flag. If the load is shorted or lower than the line impedance, a negative pulse travels back to the comparator which will have a negative threshold and will set an error flag.

The pulse generator drives the line through 100 ohms to match the line impedance, so the pulse at the input to the line is one half as high as at the pulse generator; about 1.35 volts. If the line at the transmitting end is not connected, the voltage will rise above 2.7 volts and will be detected by the comparator. In this case, the other tests will be meaningless but rather than have feedback to tell the controller, it is

■ FIGURE 3



easier to just run through all the tests.

In the case where the input to the line is shorted, there will be no signal and the comparator will not respond. I will have to use some logic to determine if that happened.

The comparator has an enable line which has this characteristic: If the enable line is pulled high when the signal is present, the output will be held as long as the enable is high. If the enable line is pulled high before (or at the same time) as the signal, the signal will not be detected as long as the enable line is high. I use this feature to prevent the comparator from seeing the initial pulse when looking for the reflected pulse.

The controller, IC2, initiates the pulse by pulling the trigger of IC1 low. The output of IC3 is fed back to Q1 to cut off the pulse so it is only as long as the response time of IC3; about 10 nS. All four lines are driven at the same time. **Figure 2** is only complete for one line. There will be three more of IC4 and 12 more SSRs and associated circuitry. All the comparators can share the bias and enable lines but it will not be possible to series all the SSRs to make them switch at the same time; more outputs from the controller will have to be used. The controller will set up the SSRs for the test. Initiate the pulse and wait for any anticipated reflection; then, set up the next test. There are four tests:

1. Check for an open at the source. Set the bias at 3V, hold the enable line low (RB0 high), and feed the comparator signal to latch W.
2. Check for a short at the source. Set the bias at 1.0V, hold the enable line low, and feed the signal to latch X. If the line is not shorted, latch X will be set.
3. Check for an open at the load. Set the bias at 0.5V, pulse the enable line (RB0 low); and feed the signal to latch Y. If latch Y is set, there is an open at the load. If latch Y is not set, then either the line is good or there is a short at the input. If latch X is set and latch Y is not, then the line is good.
4. Check for a short at the load. Set the bias at a low negative voltage and feed the inverted (notQ) signal to latch Z. If latch Z is set, there is a short at the load and the line is not good.

ANALOG ISOLATION TECHNIQUES

Q I am trying to make an ECG circuit. I am using a two op-amp instrumentation amplifier topology to amplify the small differential voltage from the body (p. 98, *Linear Circuit Design Handbook*, H.Zumbahlen, Newnes 2008). For this, I am using the dual IC op-amp OP297. I have a gain of 400. I am using a three-port isolator, the AD210 (p.110, same book), to isolate the patient from accidental electric shock. My problem is this: How do I connect the output signal from the two op-amps in — amp to the AD210? I am a student of biomedical engineering, and I enjoy your magazine. I always learn something new every time I read it. Thank you in advance.

— Fatih Surbehan, Norway

A Your instrumentation amp has one output which should be connected to pin 19 of the AD210 as shown in Figure 3 of the datasheet. If you want unity gain, then Rf = 0 and Rg = open. **Figure 3** is the complete schematic, although your preamp may differ.

400 HZ GYRO DRIVE

Q Just received my *Nuts & Volts* magazine. In regards to the question (High Voltages using Sine Waves) on page 25 of the October issue, can this idea be modified to put out say 115 VAC @ about one amp? I have seen inverters for camping using a car or battery to produce near sine waves at 60 Hz. Can this be hacked to put out 400 Hz to drive a small aircraft gyro? I need at least 100 watts. I can convert the frequency of your circuit to 400 Hz, but what is the turns ratio of the output transformer at 100 watts minimum?

— Craig Kendrick Sellen

A The modification would be to change the oscillator frequency to 400 Hz and use a transformer rated

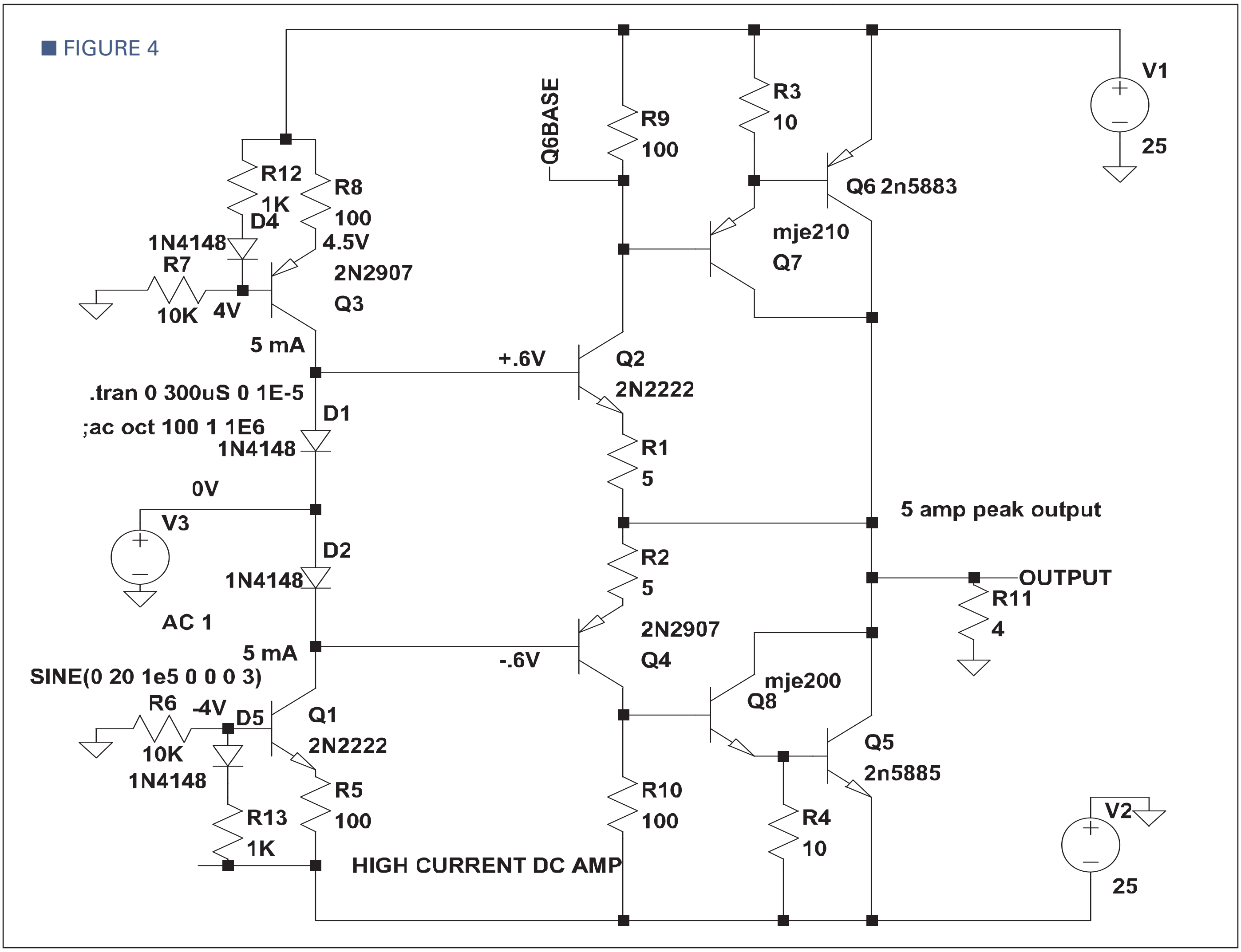


FIGURE 4

24 volts, five amps to 115 VAC 400 Hz. Inexpensive inverters produce rectangular pulses with a large dead time to simulate a sine wave. I don't know how a gyro would respond to that and I don't recommend trying to change a 60 Hz inverter to 400 Hz.

The turns ratio is the same as the voltage ratio. The peak of 115 VAC RMS is 163 volts so if you are working from 12 VDC, the ratio is 163/12 = 13.6. If the secondary current is one amp, the primary current will be 13.6 amps plus any inductive current. You will want the inductive current to be less than 10% of the load current, so wind 100 turns on the core and measure the inductive current.

If it is one amp or less, you are okay but if it is over 1.3 amps, you need to add more turns. The secondary turns will be 13.6 times the primary turns.

HIGH FREQUENCY, HIGH POWER AMPLIFIER

Q I have downloaded the datasheet for the TDA8920 amp and I have information from eBay of the kit. All I need to know is: Will this amp work with a frequency of 50 kHz? I see that the PWM signal has a carrier frequency up to 350 kHz.

— James New

A The TDA8920 will pass 50 kHz but there will be only seven samples in the sine wave. That is quite coarse and may not give the results you require. **Figure 4** is a schematic of a linear class B amplifier that I designed some time ago, I don't remember what for. It's a paper design; I did not build it. Maximum supply voltage is +- 25V, the gain is one (you will need a preamp), the response is 50 kHz, and the power output is at least 200 watts. You can increase the allowable supply voltage to 60 volts by replacing the MJE210 with STD2805 and MJE200 with STD1805. These are surface-mount transistors; a through hole version is made but not stocked. Good through hole parts are getting hard to find.

LED CHASER CIRCUIT

Q Can you please check this over before I build it? It's a 20 LED light chaser that a friend needs for a model

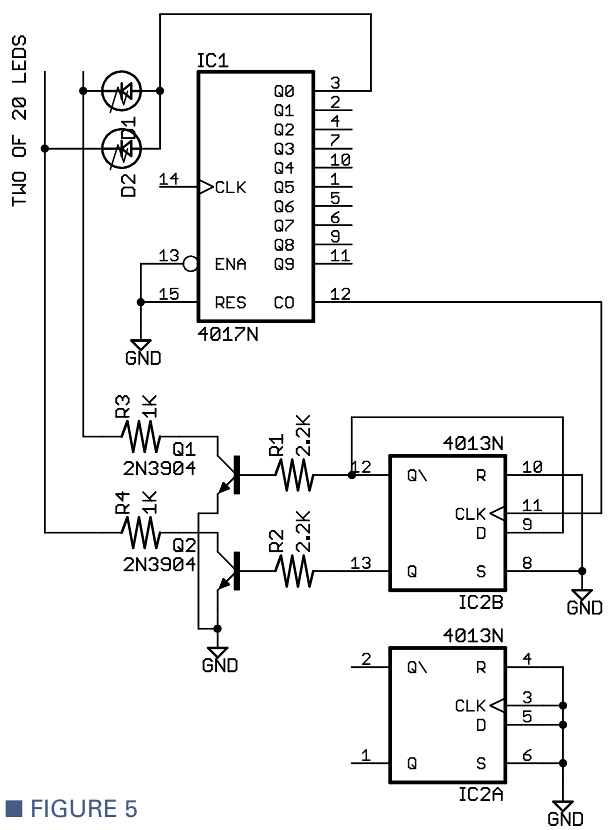
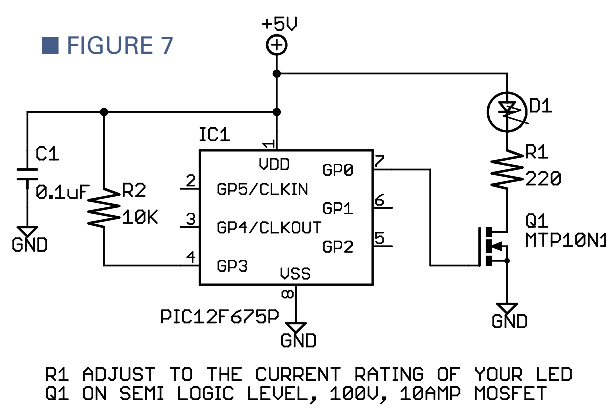


FIGURE 5

```
C:\Program Files\Mecanique\MCS\FLICKERING CANDLE.pbp

'****************************************************************
'*  Name     : flickering candle                                *
'*  Author   : Russ Kincaid                                     *
'*  Date     : 10/22/2010                                       *
'*  Version  : 1.0                                              *
'*  Notes    : A SINGLE LED IS VARIED IN BRIGHTNESS RANDOMLY    *
'*           : WHILE THE RATE OF BRIGHTNESS IS VARIED RANDOMLY  *
'****************************************************************
    REM DEVICE = 12F675
    CMCON = 7            'SETS DIGITAL MODE
    ANSEL = 0            'GPIO.0 TO GPIO.3 SET AS DIGITAL
    TRISIO = 0           'ALL OUTPUTS BUT GP3 (PIN4) IS INPUT ONLY
    VRCON.7 = 0          'TURN OFF VOLTAGE REFERENCE TO SAVE POWER
    DEFINE OSCCAL_1K 1   'TO SAVE OSCILLATOR CALIBRATION

        d VAR BYTE  'DUTY CYCLE OF PULSE, 127=50%
        t VAR BYTE  'SPEED OF FLICKERING
        J VAR BYTE  'CONTROL VARIABLE
    START:
         RANDOM d
         RANDOM d    'DOUBLED TO MAKE IT MORE RANDOM
         RANDOM t
         FOR J = 50 TO d STEP 5  'STEP 1 WAS TOO SLOW
         PWM GPIO.0,J,1
         PAUSE t         'MILLISECONDS PER STEP, UP TO 255
         NEXT J
         FOR J = d TO 50 STEP -5
         PWM GPIO.0,J,1
         PAUSE t
         NEXT J
         RANDOM d    'SINGLE TO BE DIFFERENT
         RANDOM t
         FOR J = 50 TO d STEP 5  'STEP 1 WAS TOO SLOW
         PWM GPIO.0,J,1
         PAUSE t          'MILLISECONDS PER STEP, UP TO 255
         NEXT J
         FOR J = d TO 50 STEP -5
         PWM GPIO.0,J,1
         PAUSE t
         NEXT J
       GOTO START

    END
```

FIGURE 6

FIGURE 7

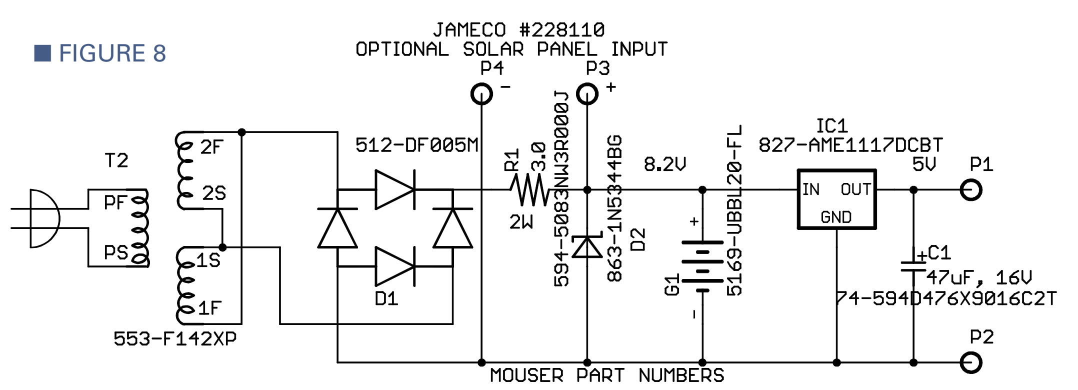


railroad runway for an airport (see **Figure 5**). Quick explanation: First, I want to use one 4017 chip, but I need a 20 LED strobe light for the runway, and only have very limited space on the board. So, I was thinking why not use the 4017 twice for the 20 LEDs.

I figured pin 12 goes high for 10 counts, and then it goes low for another 10 counts. While thinking about this, how about putting a FF such as a 4013 coming from pin 12 of the 4017. This should give me what I want — a 20 step strobe effect. My question is will this work? If so, what do I do with the other pins of the 4013 which is 1/2 used?

— Craig Kendrick Sellen

FIGURE 8



A The only change I made to your schematic is to connect the D input of the 4013 to the notQ output so that the FF toggles. Good job. The unused inputs of the 4013 are grounded.

MAILBAG

Dear Russell: Re: Thermostat for Attic Exhaust Fans, November '10, page 24. Thanks so much for your response and for publishing my question in the November issue of *Nuts & Volts*.

It occurs to me that a "heating only" thermostat is designed to turn on a furnace when the ambient temperature drops below a certain point. In my case, I want the device to turn on the fans when the temperature goes above a certain point in the attic, and turn them off when the temperature drops down to the set point.

I am thinking that I should use a thermostat that is designed for heating and air conditioning systems and set it to "cool" instead of the "heating only" thermostat you show in your schematic. Does this make sense?

— Guy Fischetti

Response: Yes, you are right. I guess I wasn't thinking.

Dear Russell: Re: Inexpensive Drafting Software, April '10, page 26.

In the November '10 issue, the first article in the mailbag discusses drafting software. Being an avid SolidWorks user and instructor, I have become familiar with a 2D solution which has been available for only a short time. It's called DraftSight and works very similarly to its big name competitor, and not the LT version. The major difference is that it is free to download. Go to **www.3ds.com/products/draftsight** for more information and a download link.

— David Urasky

Response: Thanks for the info, David. If anyone uses this software, I would be interested in more feedback.

Dear Russell: Re: PC Board Current Capacity, January '10, page 25.

The Military has documents defining the design requirements for printed wiring boards.

Look at MIL-STD-275 Printed Wiring for Electronic Equipment (**www.dscc.dla.mil/Downloads/MilSpec/Docs/MIL-STD-275/std275.pdf**). For Type 1 single-sided board, see Figure 4a, page 34. Type 2 Interior layers, see Figure 4b, page 35.

— Glenn G.

Response: I am sure many of our readers who are dealing with a high current layout will appreciate this data. Thank you.

FLICKERING CANDLE

Q I belong to a synagogue that has an eternal light fixture containing a low wattage bulb which needs moving on a regular basis. As a consequence of moving, it is occasionally dropped, usually necessitating the replacement of the lamp. Years ago, we developed a flickering circuit which would give the appearance of a flickering flame when in position. I think the time has come to move the circuitry into a more reliable design using LEDs. Could you help me with a circuit that would cause four to six orange-yellow LEDs to appear to flicker randomly like a candle and provide a means of battery backup capable of powering the unit continuously through power failures of up to 12 hours? Because of its small size and large power density, a lithium-ion cell would be preferable. A truly nice bonus would be if it was capable of running off solar cells so it could be truly eternal and free of the power company. Thank you for your help.

— Tom Holloway

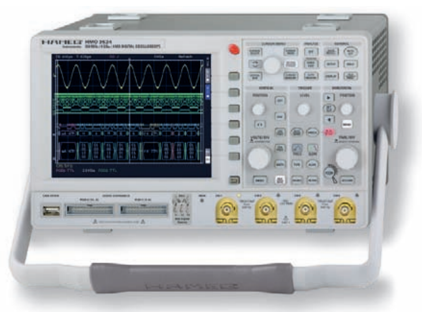
A In the October issue, page 38, Jon McPhalen wrote a very good article on this very subject. I was mostly interested in the mechanics of making the candle because the software was over my head. My approach using Basic is rather simple: I vary the brightness and rate of brightness change using the RANDOM command. I first had only one loop of FOR-NEXT, but the pattern was easily discerned so I added a second loop; see **Figure 6**. A third loop with triple RANDOM might be even better. As usual, I can send anyone a programmed 12F675 for $5; just send your request to me at russlk@yahoo.com (that is my spam filter address). The schematic is **Figure 7**. If a single 20 mA LED is used, the MOSFET Q1 is not needed. With Q1, the LED could draw up to five amps to the detriment of battery life.

Figure 8 is the power supply; the battery is nominal 7.2 VDC, maintained at 8.2V for a full charge. The battery is rated 2.4 Ah and the load is 30 mA so the light will operate for 80 hours with no input power. If the solar panel is used for the only power, consider that the daily power used is .03A X 24H = 0.72 AH. The solar panel is active for about four hours, so the panel output has to be 0.72/4 = 180 mA at minimum. Two of the 100 mA rated Jameco solar panels in parallel should work as long as there are not extended rainy days. The panels no doubt produce some power even on cloudy days. **NV**

NEW PRODUCTS

- HARDWARE
- SOFTWARE
- GADGETS
- TOOLS

NEW FUNCTIONS FOR HMO352X SERIES



Shortly after the market introduction of the HAMEG HMO2524 oscilloscopes, the built-in bus signal source turned out to be a popular feature. This signal source with four terminals takes up to four bits' wide parallel data (stochastic bit pattern or counter output), SPI, I^2C, or UART/RS-232 signals with user data as a reference directly from the oscilloscope. This helps to perform the usually complex settings with a known signal so the user can turn more quickly to his measuring problem. HAMEG has now implemented this feature in the (350 MHz oscilloscopes) HMO3522 and HMO3524. A firmware update extends the application areas of the whole HMO series. New features include: selectable interpolation (linear, pulse, sin x/x); selectable number of data for FFT analysis (two to 64K); new screen print-out format; new parameters for automatic measurements; additional cursor measurements; and additional mathematical functions (e.g., digital filters). The firmware is available to all users of HMO series oscilloscopes at no cost for downloading.

For more information, contact:
HAMEG INSTRUMENTS
Web:
www.hameg.com/HMO3524

PROBEE ZIGBEE MODULES AND ADAPTERS

Lemos International, now offers a ProBee ZigBee product line that includes a ZigBee OEM module, ZigBee USB adapter, and ZigBee serial adapter. ProBee ZigBee products are designed to meet specific requirements of low cost and low power wireless applications such as home automation or smart energy by adopting the ZigBee technology. Despite either low cost and low power consumption, these ZigBee products provide high performance and robust data transfer capability for a wide range of applications. The ProBee-ZS10 is an ZigBee RS-232 serial adapter with integrated ZigBee core and radio/antenna circuits.

The ZS10 serial adapter is designed to meet specific requirements of low cost and low power wireless applications such as home automation and smart energy by adopting the ZigBee technology certified by the ZigBee alliance based on the ZigBee 2007 and ZigBee Pro standard. The ZS10 provides high performance and robust data transfer capability for a wide range of applications.

For more information, contact:
LEMOS INTERNATIONAL
Web: **www.lemosint.com**

SOFTWARE UPDATE FOR POWDER-COATING AND THICKER MATERIAL

Front Panel Express, a manufacturer of custom-designed front panels and enclosures, has released a new version of their free design software — Front Panel Designer. This update includes options for powder-coated finishing and material thickness up to 10 millimeters. In the previous version of the software, panels thicker than four millimeters required approval from the company, as some tools were not created to work with panels thicker than 4 mm. Front Panel Designer now has the built-in ability to determine which tools are available for differing panel widths.

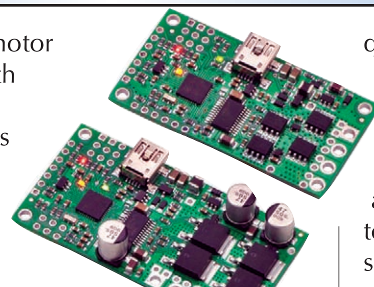
Additionally, powder-coating brings a whole new variety of colors and finishes, making these custom panels even more versatile and applicable to a wider market. As with all Front Panel Designer features, the user can see an immediate price breakdown for their custom designs.

Front Panel Designer is a tool for engineers, designers, and do-it-yourselfers to custom design their front panels and enclosures. It is a WYSISYG (What You See Is What You Get) application because the user gets the results as they see them on their screen. Front Panel Express has an automated process to machine these designs with modern CNC technology on aluminum or plastic panels, or on customer provided material.

For more information, contact:
FRONT PANEL EXPRESS
Web:
www.frontpanelexpress.com

SIMPLE MOTOR CONTROLLERS

Pololu announces the release of their simple motor controllers — a line of motor drivers with enhanced capabilities that make basic control of DC motors easy.



With four supported high-level interfaces — USB for direct connection to a computer, TTL serial for use with embedded systems, RC hobby servo pulses for use as RC controlled electronic speed control (ESC), and analog voltages for use with a potentiometer or analog joystick — and a wide array of configurable settings, these devices simplify controlling motors in a variety of projects. Units can be paired to enable mixed RC or analog control of differential-drive robots, and they can be daisy-chained with additional Pololu servo and motor controllers on a single serial line. A free configuration program (available for Windows and Linux) allows for quick controller configuration over USB (no more DIP switches or jumpers) and simplifies initial testing.

Controller features include: acceleration and deceleration limits to decrease mechanical stress on the system; optional safety controls to avoid unexpectedly powering the motor; a wizard for automatic RC and analog input calibration; and support for limit switches.

The controller versions offer a wide operating voltage range up to 5.5-40V and continuous current ratings from 12A up to 25A, which means they can deliver up to several hundred watts in a small form factor. Unit prices are $39.95, $43.95, $54.95, and $59.95 for the 18v15 (item #1377), 24v12 (item #1379), 18v25 (item #1381), and 24v23 (item #1383), respectively.

For more information, contact:
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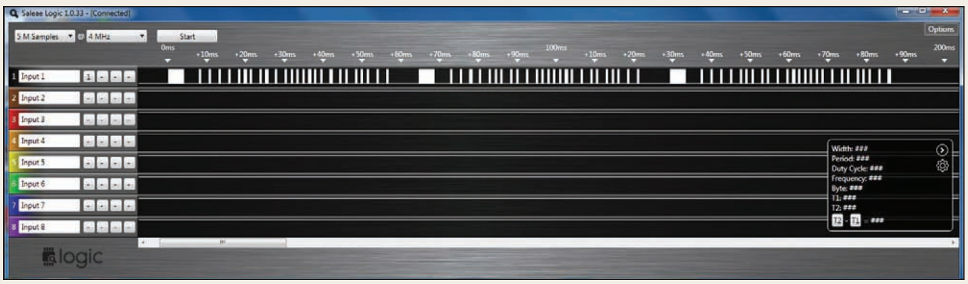
Continued on page 78

ARDUINO CHANNEL SURFER & OTHER DIABOLICAL GADGETS

By Andy Sullivan

A TV remote control uses pulses of infrared (IR) light to communicate. The pulses are transmitted with an IR LED as a series of bursts separated by off periods. **Figure 1** shows a typical transmission. Note that the total signal is almost 90 milliseconds long, contains approximately 78 bursts, and the durations of bursts and off periods vary.



■ **FIGURE 1.** Typical transmission from an infrared remote control. Many bursts and off periods of varying durations. Total transmission approximately 90 milliseconds long.

With an understanding of the IR codes, a wide range of devices can be built delivering new remote control capabilities. An example is a channel surfer that automatically flips cable channels similar to the scan function on radios. Another example is a customized remote that turns on all entertainment center components with a single button, and manages all component switching with single button presses (turn on the DVD and select the appropriate input on the TV). This might help a grandparent who struggles getting three components configured properly. Other examples include prank devices that change channels, volume, or turn off a large number of TVs with a single button press such as the TV-B-Gone advertised on the Internet.

This article will review how to build a channel surfer that will change the channel on over 200 different TVs. It is a variation on the TV-B-Gone, but has an advantage around a large number of TVs. If activated twice, the channel surfer will change the channel again causing more confusion where the TV-B-Gone will turn a TV off then back on. The concepts learned in this project can be used to create a wide range of other IR control devices.

More on IR Codes

IR signals vary widely and the one shown in **Figure 1** is just an example. The signal — or code — is different for each button on a remote. It is also different for each piece of equipment (TV, DVD, cable box). Manufacturers use different codes, and different models from the same manufacturer may use different codes. Although there are a lot of codes, it isn't a problem as the number can be trimmed to a manageable level for most projects.

A remaining structural element of an IR code is burst modulation. Each burst is composed of a series of quickly modulated flashes. **Figure 2** shows a magnified segment of the same code shown in **Figure 1**. The full code is almost 90 milliseconds long. The first narrow burst starting at eight milliseconds is expanded in **Figure 2**. The burst duration is about 0.5 milliseconds and contains 28 flashes. Each flash has a duration of approximately nine microseconds with a 50% duty cycle (off time is also 9 microseconds). Frequency of the modulated flashes is about 55 kHz.

The reason for modulation of the IR bursts is to help

■ **FIGURE 2.** Zoomed in view of burst at eight milliseconds. Burst is comprised of 28 flashes of infrared light at 56 kHz. Each flash is about nine microseconds long.

the receiver separate out IR code information from background light.

IR Code Sources

A universal remote control contains an abundance of IR code data. These are available for about $9 at department and electronic appliance stores. Look for a remote that stores many codes with a manual code search to scroll one-by-one through the codes. This functionality allows for easy code capture. For example, more than 200 codes are easily captured from a GE 24991 three-Device remote control.

Capturing Codes

The circuit used to capture IR codes centers on an IR receiver module such as RadioShack part number 276-640. The circuit is shown in **Figure 3** and it uses an Arduino Duemilanove to collect and send the codes to the PC. The IR receiver in this example was taken from a broken DVD player.

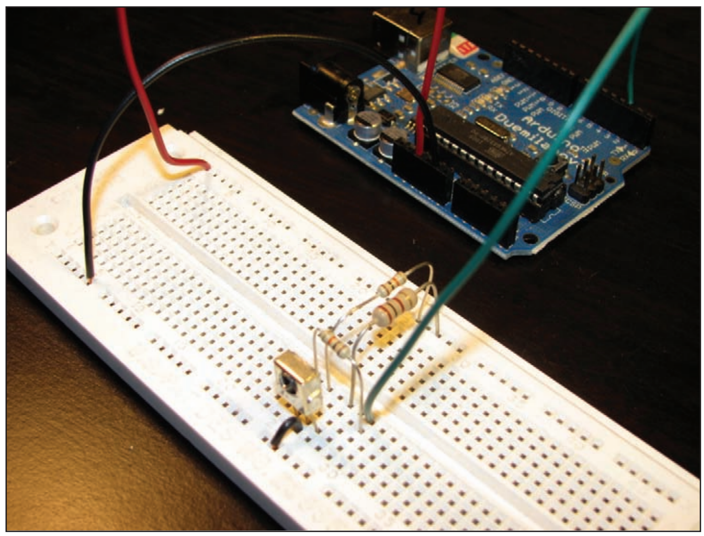
Figure 4 is the schematic for the circuit. It works by holding pin 2 high until an IR signal is detected, then pin 2 goes low. The receiver outputs a constant signal when it detects the modulated carrier signal. Or put another way, the signal will appear like **Figure 1** with the rapid flashes shown in **Figure 2** removed. This is an efficient way to capture data because each flash is not signaled which greatly reduces the amount of data to manage.

A concern with this method is that the IR receiver module is designed to capture a given modulation frequency. For example, 38 kHz in the case of the RadioShack module. Signals at very different frequencies may not be reliably detected. A validation check showed good results with a signal at 55 kHz, so the large majority of codes will be captured effectively with this method.

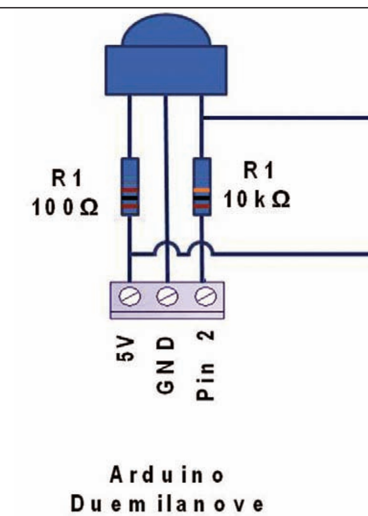
The Arduino program for capturing codes named "Code_Collector" is short and is provided in the downloads section for this article. It utilizes interrupts to scan for signal changes from the receiver module, records the time in microseconds, then stores the data in an array. When the code is collected, the program automatically calculates burst durations and outputs the data as an Arduino statement. This makes for easy copy and paste of the data into the program that transmits the codes. Here's a short example output:

```
PROGMEM prog_uint16_t code13[19] =
{38000,17,114,115,341,115,226,2679,114,115,341,11
5,226,2679,114,114,341,115,226};
```

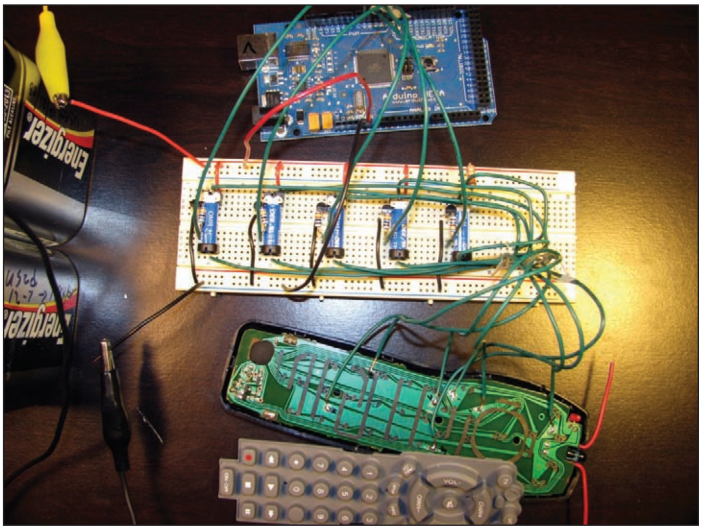
This statement will store the code in Arduino Flash memory. As an example of how to decipher the code, this one is code 13 and has 19 elements. The modulation frequency is 38 kHz. There are 17 pulse durations (19 elements minus 1 element that holds the frequency, and minus 1 element that holds the number of pulses). The first pulse is always an "on" pulse and, in this case, it is 1.14 ms long (114/100). There is then an off pulse of 1.15 ms, on for 3.41 ms, and so on. The pulse durations are multiplied by 100 to avoid the need for decimals.



■ **FIGURE 3.** Circuit to capture IR codes using an IR receiver module.



■ **FIGURE 4.** Schematic for IR receiver. It works by holding pin 2 high until an IR signal is detected; then pin 2 goes low.



■ **FIGURE 5.** Universal remote control hacked for control by Arduino. Reed relays simulate button presses.

Collect codes using the instructions for your universal remote. For the GE 24991, start at the first code by holding setup until the light stays on, press TV, then enter "0000." Point the remote control at your IR receiver and press the button you wish to capture. The code will print on the serial monitor. Move to the next device/code by holding setup until the light stays red, press TV, press channel up, then press enter. Collect the code and repeat. There will be more than 200 codes. You can capture codes using this method for any function you wish: channel up, channel down, volume up, etc. Codes for channel up, power off, and volume up are available in the downloads section in the source code.

Automating Code Collection

Collecting a complete set of codes manually takes quite a bit of button pressing on a universal remote. A more satisfying approach is to use the Arduino to run the remote control. **Figure 5** is a photo of the completed circuit. It allows the Arduino to "press" the buttons on the remote control by connecting reed relays in parallel with the remote control buttons. When the Arduino closes a relay, that button is "pressed."

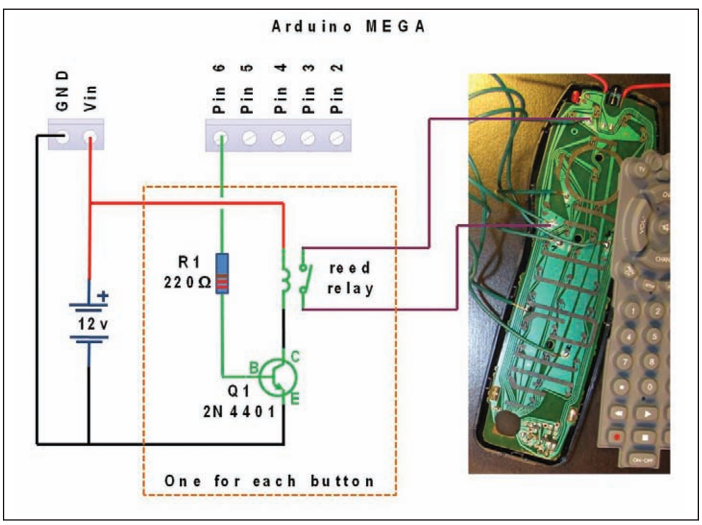
To connect the relays, a little studying of the disassembled remote control board is required. Make a list of the buttons you need pressed, then locate the copper traces connected to each side of the button. Find an area on the trace wide enough to solder to, sand off the varnish, and solder on a wire. To help keep track of things, it is best to number the wires and write down the two wire numbers that correspond to the buttons on your list. In the case pictured, there are five buttons controlled with seven wires (the buttons share wires).

Figure 6 is a schematic of the hook-up. A mix of five and 12 volt reed relays were used for this project because they were available in the spare parts box. NPN transistors were used to drive all the relays from the Arduino, although they are probably not needed for the five volt reed relays. A 220 ohm resistor is placed between the Arduino pin and the transistor base to limit current. Two six-volt lantern batteries power the system. A 330 ohm resistor is used on the five volt reed relay to limit current to the appropriate 11 milliamps.

The Arduino program for running the remote control is named "Controller" and is also provided in the downloads. It is a short program that sets one of five pins to high for brief periods. These actions cause the reed relays to close and simulate button presses on the remote control. A quarter second button press works well. Too long of a press, and the remote control signal becomes longer than necessary. This version sends each code three times so they can be reviewed for consistency.

Two Arduino boards are used to automatically collect the codes. One board is used to run the remote control and is running the program "Controller." A second board is connected to the IR receiver, is running "Code_Collector," and is sending the collected codes to the serial monitor. Attempts to perform both functions at the same time using one Arduino board produced corrupt codes. This was due to the fact that the button press routine terminates the press in the middle of a code collection. The processing overhead interferes with timing as the signal is being decoded. A solution would be to use a timing circuit with a 555 chip to press the button for a quarter second so the Arduino is free to collect the code.

To use both boards together, first set up the "Code_Collector" so it's ready to receive IR signals. Hook this to your PC and turn on the serial monitor. Reset the universal remote control to the first code; for the GE 24991, this is "0000." Finally, power up the second Arduino running "Controller" with the hijacked remote control pointing at the IR receiver. The collected codes will start printing to the serial monitor, ready to copy



■ **FIGURE 6.** Schematic for Arduino interface to the universal remote control. One of five reed switch modules shown.

to your IR transmitter.

The Transmitter Circuit

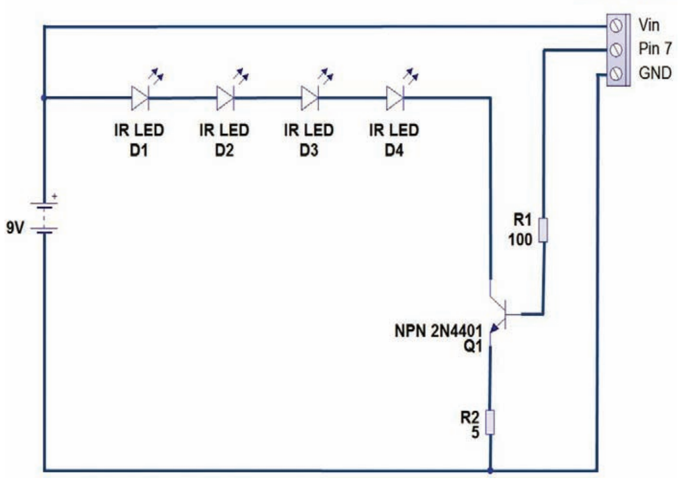
Figure 7 shows a schematic of the transmitter circuit. A nine volt battery powers the Arduino MEGA. An Arduino Duemilanove, Uno, or equivalent will work as long as you don't try to store too many codes. For the off code example demonstrated in this article, the code compiled to almost 38,000 bytes with 211 codes. The Duemilanove has a maximum 30,720, so the MEGA was used. Researching the Internet will reveal clever data compression techniques, but the C code becomes complicated. It is easier to stick with straightforward code and either a larger processor or less remote control codes.

NPN transistor Q1 is used to boost the digital signal from the Arduino MEGA and power the IR LEDs. A 15 pack of resistors from RadioShack was used as a source and contains three different transistors: 2N3904, MPS2222, and 2N4401. A little more Internet research showed the 2N3904 had a lower collector current rating of 200 mA. The 2N4401 has a rating of 600 mA which yields more power. The 2N4401 is also rated for a peak current of 800 mA which is more than ample for this project. The MPS2222 should also work as the specs are similar to the 4401.

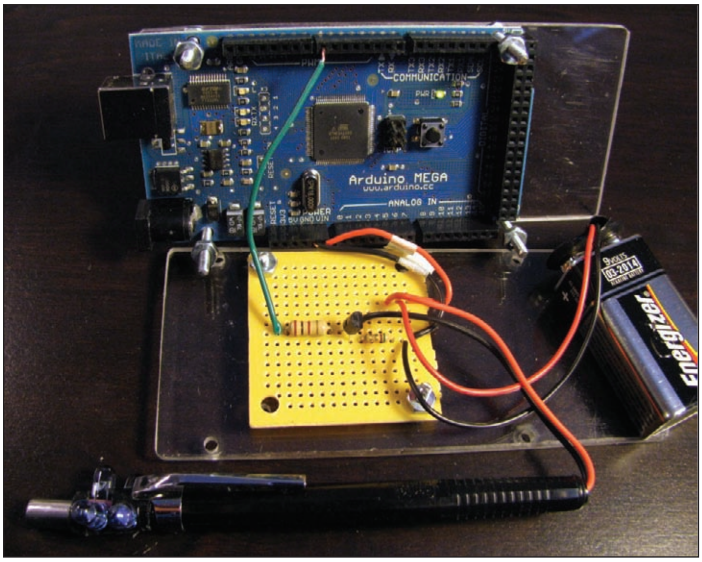
Resistor R1 limits current from pin 7 of the Arduino to a safe level. In early tests, a value of 560 ohms was used to protect the Arduino, even with some kind of malfunction in the transistor or mis-wire; 560 ohms was chosen based on a maximum current at five volts divided by 560 ohms is 9 mA which is well within maximum spec of 40 mA. Follow-up testing on the circuit showed IR LED output was a little low compared to a TV remote control (use a digital camera to view the IR LEDs in action). Using an oscilloscope, the voltage on the base of the transistor never dropped below 1.9 volts. With an Arduino pin voltage of five volts maximum, the max voltage driving force is 5-1.9 = 3.1 volts. A 100 ohm resistor limits current to 0.031 amps — within the Arduino spec of 40 mA — and yields considerably more IR output.

Four IR LEDs were used in series to maximize IR signal output and utilize the nine volts available from the battery. Four LEDs in series yields a total voltage drop of 4.8 volts based on the rated forward voltage of 1.2 volts. The LEDs are rated at 100 mA continuous, but it is not clear from the packaging or RadioShack website what the peak current limit is. Looking at specs for other LEDs with similar continuous current ratings showed peak currents in the 1-2 amp range which is ample for this circuit. Continuous current limits at 100 mA will limit peak currents to 400 mA based on a duty cycle of approximately 1/4. Code bursts are about 1/2 of the code and each burst is modulated 50% for an overall duty cycle of 1/4; 400 mA * 1/4 duty cycle = 100 mA. This is conservative as there is more off time than on time in the codes.

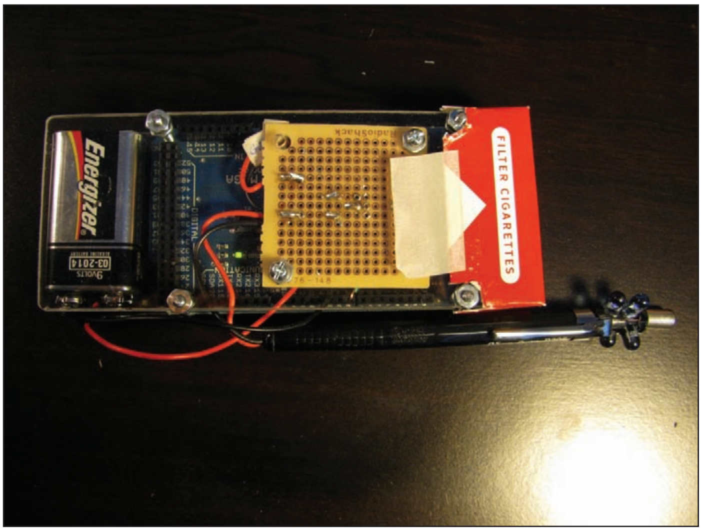
■ **FIGURE 7.** IR transmitter schematic.



Resistor R2 limits current to the IR LEDs. A five ohm resistor was used from a spare parts bin, or two 10 ohm resistors from the parts list could be used in parallel. The maximum driving force is nine volts minus the voltage drop across the LEDs. At 1.2 volts each, voltage out of the LEDs and into the resistor is 4.2 volts; 4.2 volts / 5 ohms yields a high calculated current of 840 mA. In practice, the currents are smaller. The reason for this is that as current through the LEDs increases past the rated continuous current of 100 mA, the voltage drop increases beyond the rated forward voltage of 1.2 volts. At a battery voltage of eight volts, forward current was 320 mA and the voltage drop across each LED was 1.6 volts. Voltage across R2 is 8 - 1.6*4 = 1.6 volts. Current is calculated by 1.6 volts across R2 / 5.0 ohms = 320 mA. At maximum voltage with a fresh battery at nine volts, current was 426 mA which is still within the capability of the LEDs, transistor, and a good alkaline nine volt battery.

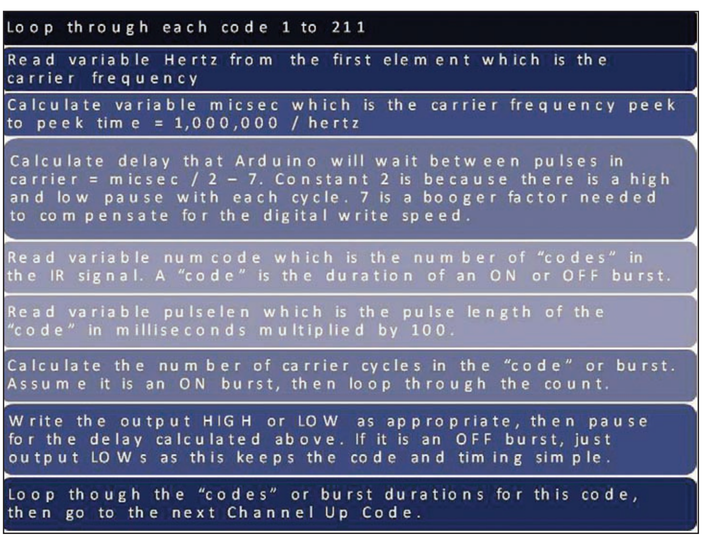


■ **FIGURE 8.** Arduino board, circuit, Plexiglas enclosure, and pen transmitter package.



■ **FIGURE 9.** The assembled transmitter.

■ **FIGURE 10.** Transmitter disguised as a pack of cigarettes and a pen in pocket.



■ **FIGURE 11.** Arduino program flowchart.

Building the Hardware

The circuit was assembled on a 1.75 inch square piece of perf board. A photo of the finished circuit is shown in **Figure 8**.

Discretion is a priority for channel changers. Along those lines, a slim packaging for the product was a priority. This is complicated a little by the size of the Mega board which has plenty of pin-out space. To keep things small, the perf board circuit was packaged in between two 5 x 2 inch pieces of Plexiglas using small screws and nuts to hold things at the proper spacing. The Arduino Mega board fit snugly in the enclosure so the whole device thickness was 7/8 inch; thin enough to fit comfortably in a shirt pocket or a jean's back pocket.

To minimize suspicion, the lid from a cigarette pack was placed on top of the enclosure. The IR LED emitters were glued into a pen which was mounted to the enclosure. The final product is shown in **Figure 9**. **Figure 10** shows the device disguised as a pack of cigarettes and a pen in a shirt pocket demonstrating its non-noteworthy appearance.

The Transmitter Program

There are three sample IR transmitter programs provided in the downloads section. "GE_Ch_Up_Codes.pde" contains 211 codes for changing the channel. There is also a version that sends power off codes, and a version that sends volume up codes.

The majority of the program is the code data. This block of code can be copied directly from the serial monitor after code collection is complete. As written, each code is sent in triplicate and needs to be trimmed. An easy way to do this is to scan the number of bursts in the second element of the array. It should be the same for each code, and has to be an odd number. Keep one of each group of three, discarding outliers if any exist.

The rest of the program is a loop of about 30 lines of code. For each code, the program loops through each burst duration. The number of flashes for a burst is calculated based on the frequency; a constant of 38 kHz for the collection method here. Then, the program enters a loop and transmits the pulses by cycling the output pin high then low. To keep timing simple, bursts and off periods are treated the same except the pin is kept low for off periods. **Figure 11** is a flowchart of how the program works.

Testing the Scrambler

Testing the device is as easy as browsing the TV selection at a local store with the project in a shirt pocket. As configured, the device will change the channel on about 60% of TVs. Range is a good aisle away. Most stores keep all the TVs on the same channel, so it doesn't take long for a clerk to ask "What's going on with the TVs?"

Testing at a local sports bar takes more care. An early prototype didn't have much result, but that was with only a single LED and a more conservative design. Follow-up testing is limited as the places tend to be packed, and risk to life and limb is an important testing consideration.

Part Description	Supplier	Supplier part #
(4) High Output Infrared LED	RadioShack	276-0143
2N4401 NPN Transistor (pk of 15)	RadioShack	276-1617
(2) 100 ohm Resistors	RadioShack	271-1108
(2) 10 ohm Resistors	RadioShack	271-1101
(2) 10k ohm Resistors	RadioShack	271-1335
(5) 220 ohm Resistors	RadioShack	271-1313
9V Battery Snap Connectors	RadioShack	270-0325
Arduino Mega	SparkFun	DEV-09152
38kHz Infrared Receiver Module	RadioShack	276-640
(5) Reed Relay at 12VDC	RadioShack	275-233

■ **FIGURE 12.** Parts List.

What's Next

The number of codes and percent of TVs impacted is acceptable for a little good natured fun. Boosting the transmit power would allow greater action at a distance. Perhaps an array of IR LEDs would function at a tremendous distance like a high power LED flashlight.

Smaller size would also have advantages. A button version would be possible that would improve stealth and would open the opportunity for a transmitter plant, maybe on a magnet. This would be a great troubleshooting exercise for your friends at the local appliance center.

Collecting the codes could be optional. The circuit board in a universal remote control is thin with most of the area used for button pads. A microcontroller could piggyback on a universal remote to send codes. This would allow development of a device with a microcontroller slower than the Arduino.

On a more constructive avenue, it would be no problem creating a customized remote control for your entertainment center. Another opportunity is a transmitter/receiver pair utilizing your own codes for control solutions in your next project. **NV**

BUILD A WI-FI SPRINKLER SYSTEM Part 2

By Bob Colwell

We have a springtime ritual at our house. My wife buys beautiful hanging baskets and distributes them liberally around the yard. If I don't quickly get the sprinkler system running, they're all doomed. Every year, something will have broken over the previous winter. To figure out what broke, I want to stand in the yard and turn the zones on and off, one by one. To do *that*, I want my sprinkler to be wirelessly connected to my home network. Thus was born this Wi-Fi sprinkler project.

The Big Picture

Last month, I explained how the Rabbit RCM5450W module works, and how to interface relays and an LCD display to it. This time, we'll see how to use those building blocks to design a Wi-Fi lawn sprinkler — one that you can control while walking around your yard with your iPod in your hand.

The best way to see how this project works is to start at the sprinkler valves. These are electrically operated water valves inside underground plastic boxes, attached by underground wires to the sprinkler control box in the garage. Put 24 VAC across the valve terminal, and approximately 75 mA will flow, the valve will actuate, and water will flow through the valve into the subnetwork of sprinkler heads downstream (the "zone.")

We can get 24 VAC from a transformer, and because we won't turn on multiple zones at once, the current requirements are a trivial 75 mA. To control this electrical current to each zone's sprinkler valve, we'll use the relays and relay interfaces we designed in last month's article.

When the Wi-Fi module is running, just browse to its IP address on the network, and presto! Click one of the zone icons, and that zone turns on while all other zones are turned off. Original problem solved.

Now we've got a manual sprinkler system that only waters the lawn when you manually turn a zone on. That seems a step backwards. We still want the sprinkler to automatically water the yard according to a schedule. We could think about having one of the computers on the home network do this by noticing the day and time, browsing to the Wi-Fi sprinkler's IP address, and "clicking on the icons" as necessary. I didn't want to do it this way, however, because I didn't like the idea that my PC and the network had to be up for the sprinkler to work. This led me to yet another requirement: the Wi-Fi sprinkler now needed to know the date and time so that it could compare those to the automatic program's requests. Rabbit sample code showed how to do that (see below). I also added code to edit the auto sprinkler schedule and see it on the website.

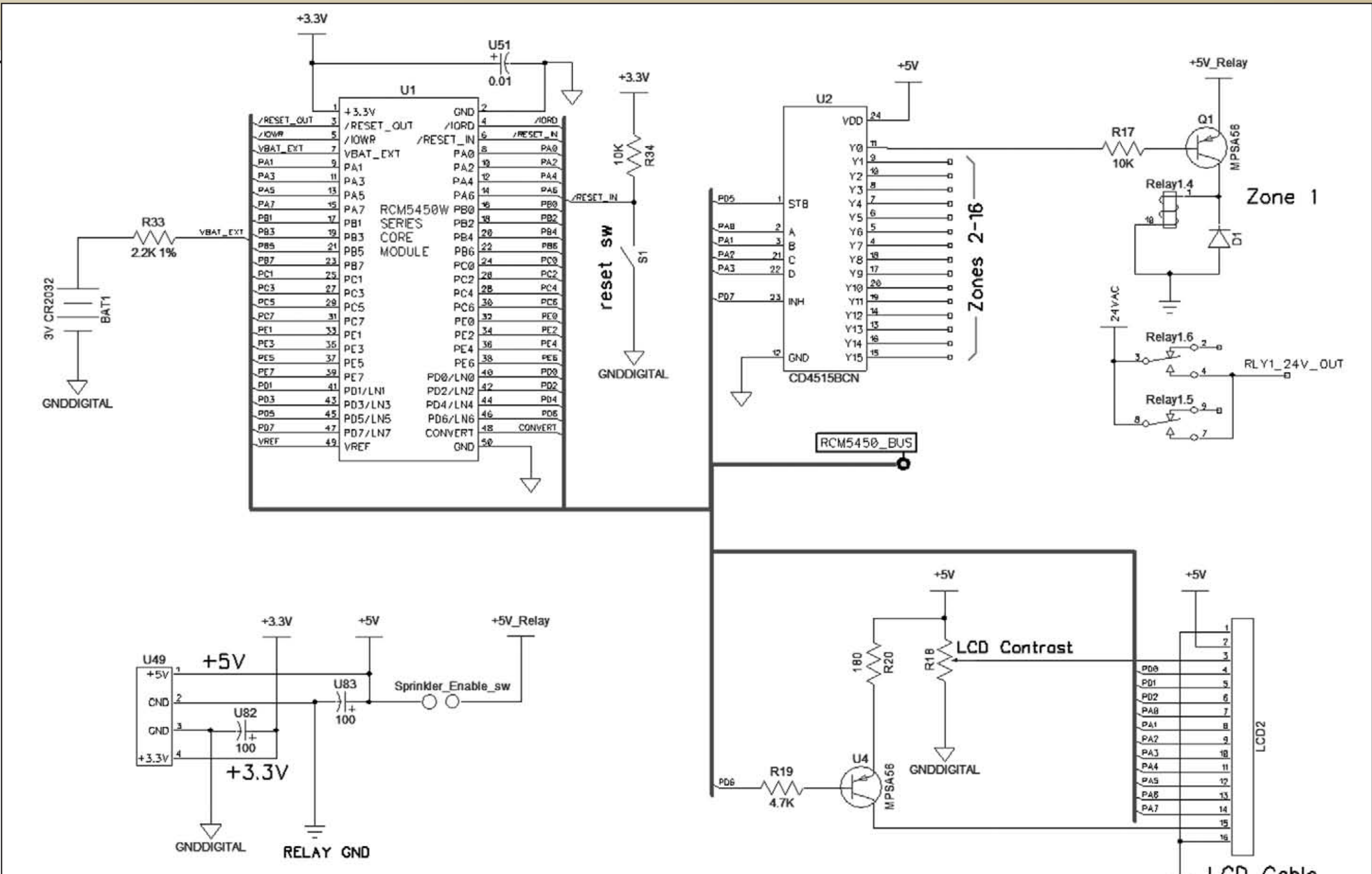
C Code Controlling Relays

Last month, I showed how to design a transistor driver to allow the Rabbit module to control a relay, and a 4515 decoder/latch chip so we can drive an LCD display at the same time. The schematic is in **Figure 1**.

To turn on a sprinkler zone, the Rabbit module strobes the four-bit number of the zone into the CD4515 chip's internal latch, and then de-asserts the 4515's Inhibit input. Here's the Rabbit C code to accomplish that:

```
relay_disable();
relay_sel(*next_zone-1);
       //CD4515 decoder maps 0 to relay 1 etc.
relay_enable();

sprinkling = *next_zone;
*current_zone = *next_zone;
lcd_show_netclk(get_local(), SHOW_ZONE);
BitWrPortI(PDDR, &PDDRShadow, ON,
LCDBacklightEnableBit);
```



■ **FIGURE 1. The Wi-Fi sprinkler schematic.**

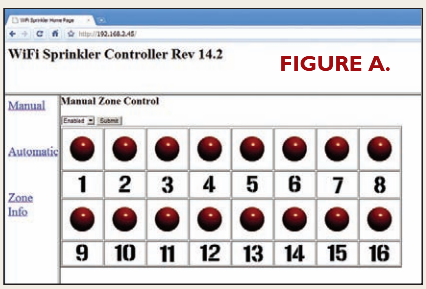


FIGURE A.

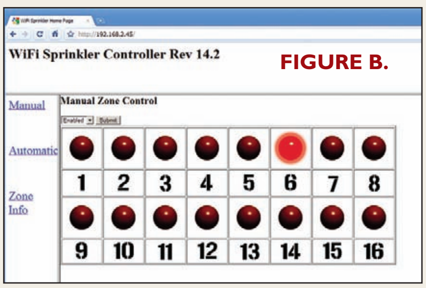


FIGURE B.

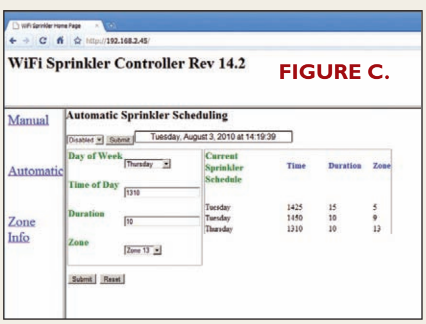


FIGURE C.

A Mere Matter of Programming

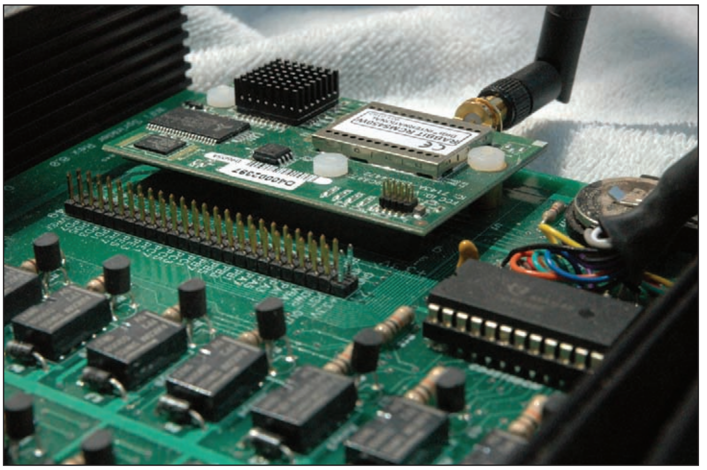
Figure A is what the Wi-Fi sprinkler home page looks like on the screen of the iPod. When you click on the zone number, the light above that number illuminates and the zone starts sprinkling. As you'll see from my HTML code, it was all written by hand by an HTML novice (me).

For example, if you click on the number 6, you see the screen in **Figure B**. The automatic sprinkling page looks like **Figure C**. The schedule for which zone to turn on, on what day, when, and for how long is kept in a Flash memory file on the Rabbit module, and is edited on the automatic page.

The "zone info" page is just a list describing which zone number corresponds to which areas of the yard.

First, we disable the relays (relay_disable() just sets the 4515 Inhibit bit). Then, we write the 4515 internal latch with the new zone number which is 1; it's decremented because the zones are numbered 1-16, while the 4515 outputs are numbered 0-15. The "current_zone" and "next_zone" code lets us remember that we've now turned on a zone because we don't want to come through this code repeatedly, disabling the relays only to turn the same one back on again. Then, the relays are re-enabled. The lcd_show_netclk call causes the LCD display to show the zone being manually sprinkled, and the BitWrPortI call is Rabbit-ese for turning on one bit of port D which turns on the LCD backlight. I wrote the relay_* routines and put them into a RPC_RELAYS.LIB library so that the C code would be easy to understand. The next time through, we follow a different path through the code, leaving the relay/zone on until the user says to turn it off. (This prevents the relays from chattering.)

Deciding when to turn on a zone for automatic sprinkling, and how automatic and manual sprinkling should interact with each other was more difficult. My philosophy was that in case of conflict, manual sprinkling should prevail, and it should disable automatic sprinkling until auto is later re-enabled. This is to prevent confusion while standing out in the yard. Look at the C code for



■ **FIGURE 2. The RCM5450W module and a 50-pin field for debug (foreground).**

details on how that was done.

C Code Controlling LCD Display

As with relay control, my C code for controlling the LCD display is based on library routines that I wrote first. The idea was to hide the grungy details of the LCD module interface, and make it easy to put text and numbers anywhere on the LCD display.

The first piece of grunge is that the LCD display can be very slow. This means you have to poll an LCD's module busy bit to see if the display is ready for a new input. That means reading the busy bit, which requires the PA port to "turn around" from being all outputs to being all inputs. Once the busy bit has de-asserted, the PA port is again changed to outputs, and the character to display is sent across the PA bits under the control of three PD bits. A library routine named lcd_busy_wait() accomplishes all that, and also has a time-out counter so that any hardware problems with the LCD display can't hang the whole system. The three PD control bits are named RS, RW, and E. RS is "Register Select," RW is "Read/Write" (1 = read, 0 = write), and E is "Enable." After initialization of the module (lcd_init()), to write a character to a specific location on the display, you put the eight-bit character on the PA lines, set RS as described in the LCD module's interface table, and "blip" the E line (E≤-1 followed by E≤-0). This functionality is embedded in an lcd_wr_char() routine in my RPC_LCD.LIB library. Here's the E bit pulse code (where EBIT is #define EBIT 2, meaning port D bit 2):

```
BitWrPortI(PDDR, &PDDRShadow, 1, EBIT);
     // LCD E bit = 1
BitWrPortI(PDDR, &PDDRShadow, 0, EBIT);
     // LCD E bit = 0
```

If you can write a character, you can write a string which is what lcd_wr_str() does in the same library.

Wi-Fi Code

One of the best things about the Rabbit development environment is the large amount of sample code they provide. I had no trouble getting the module to connect to my home network. You will need to change the PRIMARY STATIC IP to something suitable for your network. Likewise for the SSID and the KEY0_HEXSTR.

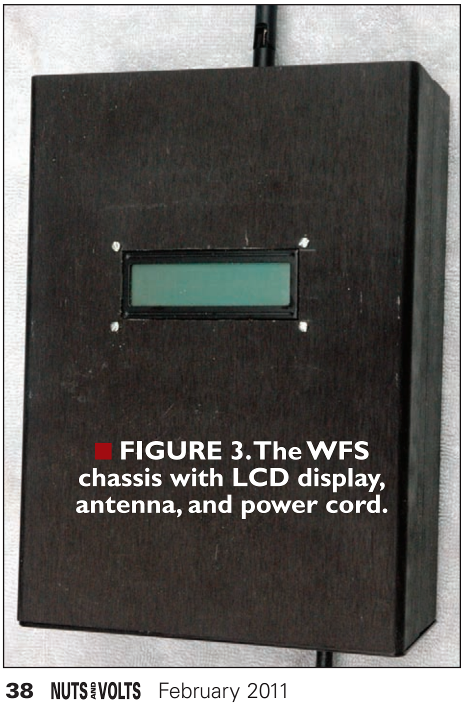
```
/*
 * NETWORK CONFIGURATION
 */
#define TCPCONFIG 1
#define _PRIMARY_STATIC_IP            "192.168.2.45"
#define _PRIMARY_NETMASK             "255.255.255.0"
#define MY_GATEWAY                     "192.168.2.1"
#define MY_NAMESERVER                  "192.168.2.1"
#define IFC_WIFI_SSID       "ColwellWirelessNetwork"
#define IFC_WIFI_MODE    IFPARAM_WIFI_INFRASTRUCTURE
#define IFC_WIFI_REGION IFPARAM_WIFI_REGION_AMERICAS
#define IFC_WIFI_ENCRYPTION    IFPARAM_WIFI_ENCR_WEP
#define IFC_WIFI_WEP_KEY0_HEXSTR         "1234ABCDEF"
```

In fact, you might not want to use a static IP, and may want something stronger than WEP. Rabbit has examples of DHCP, WAP, and many other variations. I went with static IP because it was the simplest thing I could try, and once it worked, well ... if it ain't broken, don't fix it. To get the radio running, you do this:

```
   // Initialize the TCP/IP
   // stack and HTTP server
   // Start network and wait
   // for interface to come up
   // (or error exit).
sock_init_or_exit(1);
http_init();
```

And the main do-forever loop is as follows:

```
while (1) {
   costate {
     waitfor (DelayMs(400));
     update_outputs
       (&current_zone,
        &next_zone);
   }
```



■ **FIGURE 3. The WFS chassis with LCD display, antenna, and power cord.**

■ **FIGURE 4. The power switch and power supply-chassis (24 VAC, +5V, +3.3V).**

```
    http_handler();    // costates give http
                       // handler lion's share
                       // of cycles

    costate {
        waitfor (DelayMs(500));
        tm_rd(&thetm);
        t1 = mktime(&thetm);
    }
}
```

The "co-state" C extension is cool. It gives you a way to allocate the machine's CPU cycles for best overall performance. The while(1) loop above has two costates and a call to http_handler(). The first costate waits for 400 milliseconds before calling update_outputs() which is my code that controls the relays and the LCD display. That 400 mS delay means that update_outputs() won't get called any more than about twice per second which is plenty responsive for controlling zones and displays. Likewise, the second costate waits 500 mS before updating the clock. Again, twice per second accuracy is more than good enough for our purposes. All remaining CPU cycles are devoted to the task of running the web server and radio, thus making the site feel snappier when you browse to it.

Net Knows Time and Date

When the Rabbit module boots, it first brings up the radio and connects to the home network. After that, it goes out on the Internet to certain specific time-and-date sites to update the module's internal clock, like so:

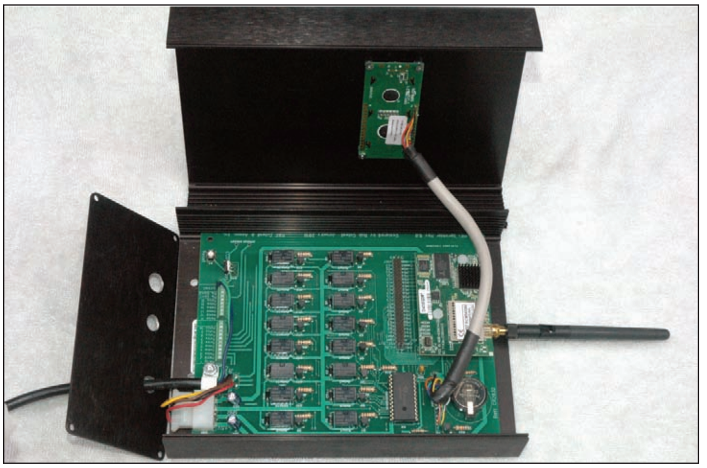
```
// Find the time from
// the internet resources.
get_the_time();
tm_rd(&thetm);
t0 = mktime(&thetm);
```

Here are the sites that it tries, one after another, until one of them works:

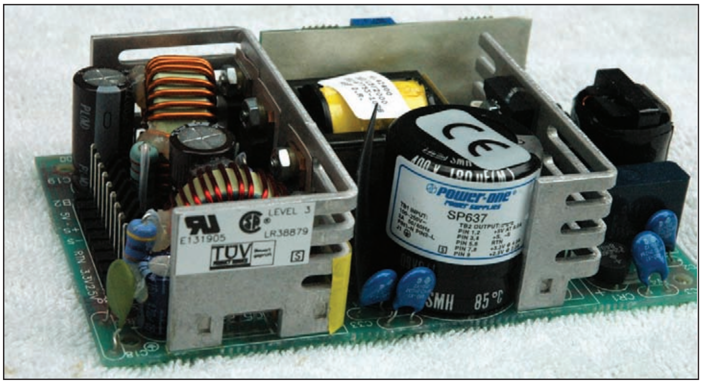
```
// Hostnames (or dotted quad
// IP addresses) of each
// time server to query.
char * const server_hosts[] =
{
    "time-b.nist.gov"
  ,"nist1.aol-
ca.truetime.com"
  ,"0.pool.ntp.org"
  ,"1.pool.ntp.org"
  ,"2.pool.ntp.org"
  ,"pool.ntp.org"
};
```

This polling seems to take only a few seconds during the module boot. The only change I had to make to Rabbit's sample code had to do with Daylight Savings Time (DST) which is not automatically handled by any of these sites.

At first, I tried writing code that would accurately reflect DST



■ FIGURE 5. The WFS prototype chassis opened up with the LCD cable, PC board, and chassis top removed.



■ FIGURE 6. The 5V and 3.3V power supply module.

PARTS LIST

ITEM	DESCRIPTION	SOURCE
BAT1	Battery	3V CR2032
Batt Skt	Battery socket	All Electronics BH-62
J1-J2	10-pin terminal	Mouser 651-1725737
LCD1	LCD display	Mouser 763-0216K1Z-FSA-GBW
Q1-Q16	MPSA56	TO92 PNP Transistor
R1-R16	10K 1/4W resistor	Jameco 691104
R33	2.2K 1% 1/4W resistor	Jameco 690945
R34, R36	10K 1/4W resistor	Jameco 691104
R35	10K potentiometer	Digi-Key 3352W-103LF-ND
R37	180 1/4W resistor	Jameco 690689
RCMpins	2x25 pin header 0.1" pitch	Mouser 70287-1219
Relay1-16	FP2 subminiature 5V relay	Mouser 655-D3009
S1	SPST switch PCB mount	Jameco 149948
U1	Rabbit RCM5450W	Rabbit RCM5450W
	50-pin 0.05" pitch socket	Mouser 855-M50-3002545
All diodes	1N4001	Mouser 512-1N4001
U2	CD4515BCN latched 4:16 decoder	Mouser 595-CD4515BE
U49	Four-pin pwr rt angle PCB header	Digi-Key WM6988-ND
U51	Capacitor 0.01 µf	All Electronics RMF-103
U82-83	Capacitor 100 µf	Mouser 75-515D107 M016AA6AE3
Power supply	5V, 3.3V supply	All Electronics PS-637
USB programming cable		**www.rabbit.com/products/sb-prg-cable/buyOnline.shtml**

The Gerber file for the PCB is available in the downloads file for this article.

start and stop dates for the indefinite future, but that was hard because the DST rules are rather informal: “DST starts at 2 am on the second Sunday in March and ends at 2 am on the first Sunday of November.” Instead, I just made a table with the DST start/stop dates for the next 15 years and I use that to adjust the inputs from these time/date sites.

50-Pin RCM5450W Repeater

Early in this project — as I was debugging my initial code for controlling relays — I was faced with a mystery: The relays were “chattering,” implying one or more of them was turning on and off rapidly, or maybe the relay drive circuit was behaving erratically. To track the problem down, I wanted to use my scope and my logic analyzer, but there were no convenient places to attach the probes because the guy who designed the board (me) had not provided any. I fixed that omission on the next revision of the board by bringing every module interface signal to a pin staked to the board in a standard 1/10” configuration. That turned out to be a really good idea (although it was by no means trivial to hand route all 50 lines from the Rabbit socket over to the pin field), but it got even better when I remembered to label each pin on the next board rev’s silkscreen.

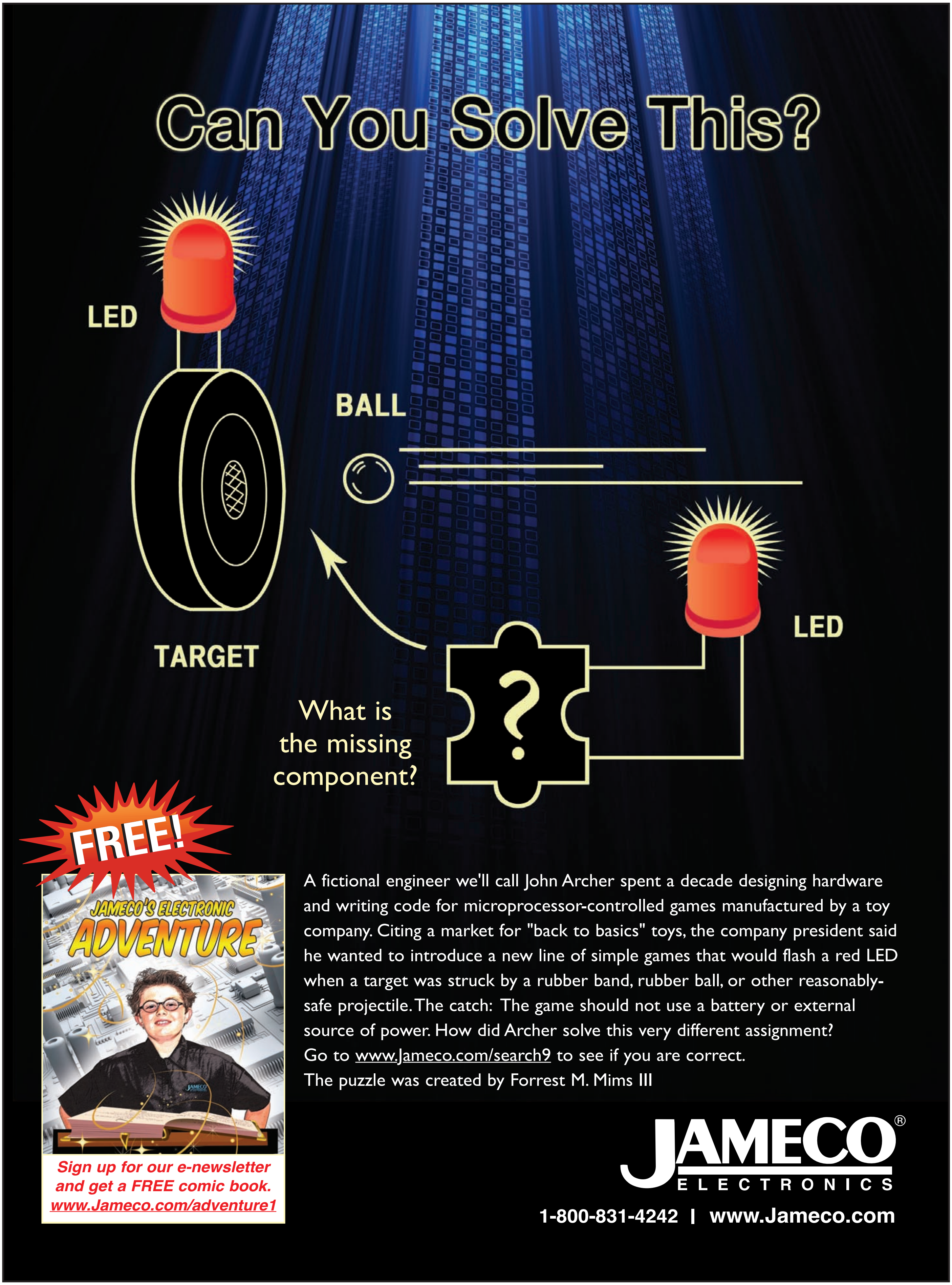
Rabbit’s C Compiler

The Rabbit RCM module is available from Digi-Key. The Rabbit C compiler is available free from Rabbit at **www.rabbit.com/support/downloads/dc/dc10.shtml**. Then, all you need is a programming cable (available for $39 at **www.rabbit.com/products/usb-prg-cable/buyOnline.shtml**). The rest of the code and files needed for this project can be found at the article download link. There is also a README file which describes the various files and directory structures.

Wrap-Up

This article has covered the basics of the Wi-Fi sprinkler project hardware. I’ve tried to give some rationale for the choices made in its design, including the LCD and relay interfaces which will impact the programming necessary to make all this work. Besides making a dandy sprinkler system controller, this design is very general – a low cost, networked, wireless controller that knows the date and time, has a Flash file system beneath it, lots of sample code, and is a lot of fun. Use it for sensing, controlling, monitoring ... your imagination is the limit. I have a couple of things in mind already. **NV**

Bob Colwell was Intel’s chief Pentium microprocessor architect for most of the 1990’s. Before that he was a hardware engineer at VLIW minisupercomputer startup Multiflow Computer, a hardware design engineer at workstation vendor Perq Systems, and a member of technical staff at Bell Labs. He has 40 patents and is the author of The Pentium Chronicles. He is currently an independent consultant.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BUILD A WALL WART POWER MONITOR

By David Goodsell

As an experimenter, I use wall warts all the time to power circuit boards, microcontroller boards, and even finished projects. However, during the checkout phase of a new circuit, wall warts present a problem. How do you measure their output when they're plugged into a board or project box? Figure 1 **illustrates the problem and** Figure 2 **presents the solution.**

The Need

Why is there a need to measure the output of a wall wart, you might ask? There are two reasons: current and voltage. For example, is your circuit drawing the predicted amount of current? Is the current more than the wall wart is designed to handle? Is the voltage sufficient to drive any downstream regulators under full load conditions? Or, is the voltage too high, putting a large heat burden on the regulators?

That's where the unit described in this article comes in. I call it the Wall Wart Power Monitor. It's a self-contained, in-line, battery powered unit that measures both DC current and voltage. It accepts four of the most common types of wall wart plugs and, in turn, has four identical output plugs, ready to hook to your project.

Requirements

Coming from a background in the aerospace industry, when I start a new project I immediately think of generating a 200 page System Requirements document. Since I'm retired now, I have to keep myself in check. A list of basic requirements is still useful, so, here goes.

Requirements:
1. Low cost.
2. Compact size.
3. Self-contained (no external power required).
4. Can measure wall wart DC outputs from 3.3 VDC to 24 VDC.
5. Can measure currents of at least two amps.
6. Interfaces with the most common wall wart connectors.
7. Can handle both positive and negative pins.
8. If battery powered, the battery must last for several months.

Other Desirable Features:
1. Uses power from the wall wart to drive the circuitry.
2. Has an LED to indicate when unit is on.

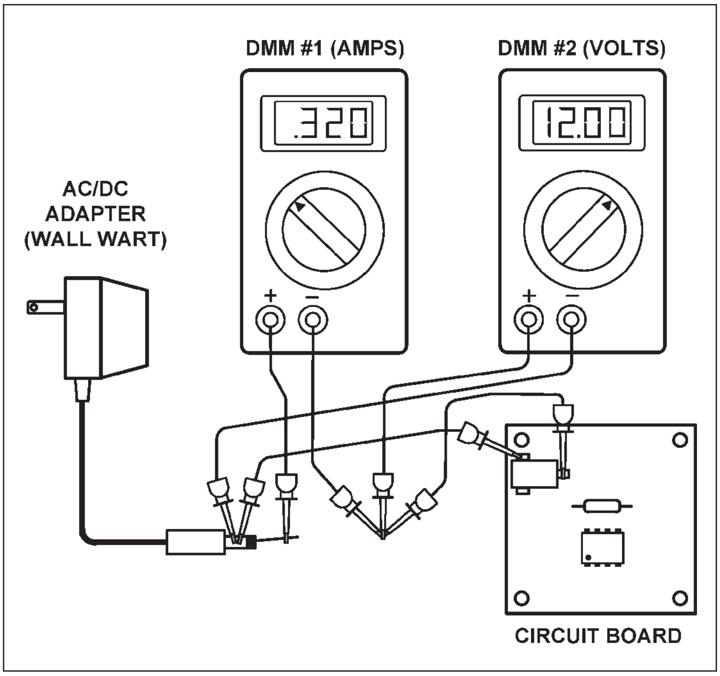


FIGURE 1. The old way to measure voltage and current from a wall wart.

3. Uses surface-mount components to reduce size.

Circuit Design

The first item to select was the LCD voltmeter. Digi-Key listed three models of Martel's low-cost V-Series voltmeters for under $30. Let's look at the specs: +-200 mv full scale, with auto-zero and auto-polarity. User selectable decimal points. Three samples per second. Power requirements are 7-12V at a paltry 1 mA. Three sizes of numerals are available: 0.25", 0.50," and 0.60". I chose the 0.50" size so I could read it across the bench.

Unfortunately, these meters have a downside. They require an *isolated* power supply, like a 9V battery. You are not allowed to connect the minus (or plus) of the power supply to either input, i.e., a common ground, due to the V-Series' internal circuitry. There are tricks you can use — like plus and minus supplies — but that's usually not practical. One nifty solution would be to employ an isolated DC-DC converter, which I'll discuss later on.

■ **FIGURE 2.** The new self-contained in-line Wall Wart Power Monitor displays readings either continuously or at the touch of a button.

Now ... what about battery life? A quick search of the Internet for the specs on a 9V Duracell Coppertop showed a life of 250 hrs with a 2 mA load and 7V cutoff. The Martel unit only uses 1 mA which means the service life would be approximately 500 hrs. Therefore, if it was used for four hrs/day, we could expect a lifetime of 125 days. Sounds good.

Then, I had a brainstorm. When I'm checking out a circuit, I seldom need to read the voltage or current continuously; a brief look now and then is usually enough. This would also extend the battery life. So, I added the auto-turnoff circuit shown in **Figure 3**. In operation, each time the button is pushed, it charges the 10 mF capacitor, turning on the FET and LCD. When the button is released, the one meg resistor slowly discharges the cap until it falls below the Gate Threshold Voltage (VGS(th)) of the FET and turns off the LCD.

Since the FET was being used as a switch, I wondered how much current — if any — might still be flowing when it's turned off. Would it drain the battery? A check of the spec sheet showed a maximum Zero Gate Voltage Drain Current (IDSS) of just 1 µA — not a problem.

I double-checked the auto-turnoff circuit on a solderless breadboard to make sure my calculations and assumptions were valid.

This brings us to the DC-DC converter that I mentioned earlier. The idea was to use a small amount of power (1 mA) from the wall wart to power the LCD. The biggest problem was that the input voltage could vary from 3.3 VDC to 24 VDC, which is a major stretch for most DC-DC converters.

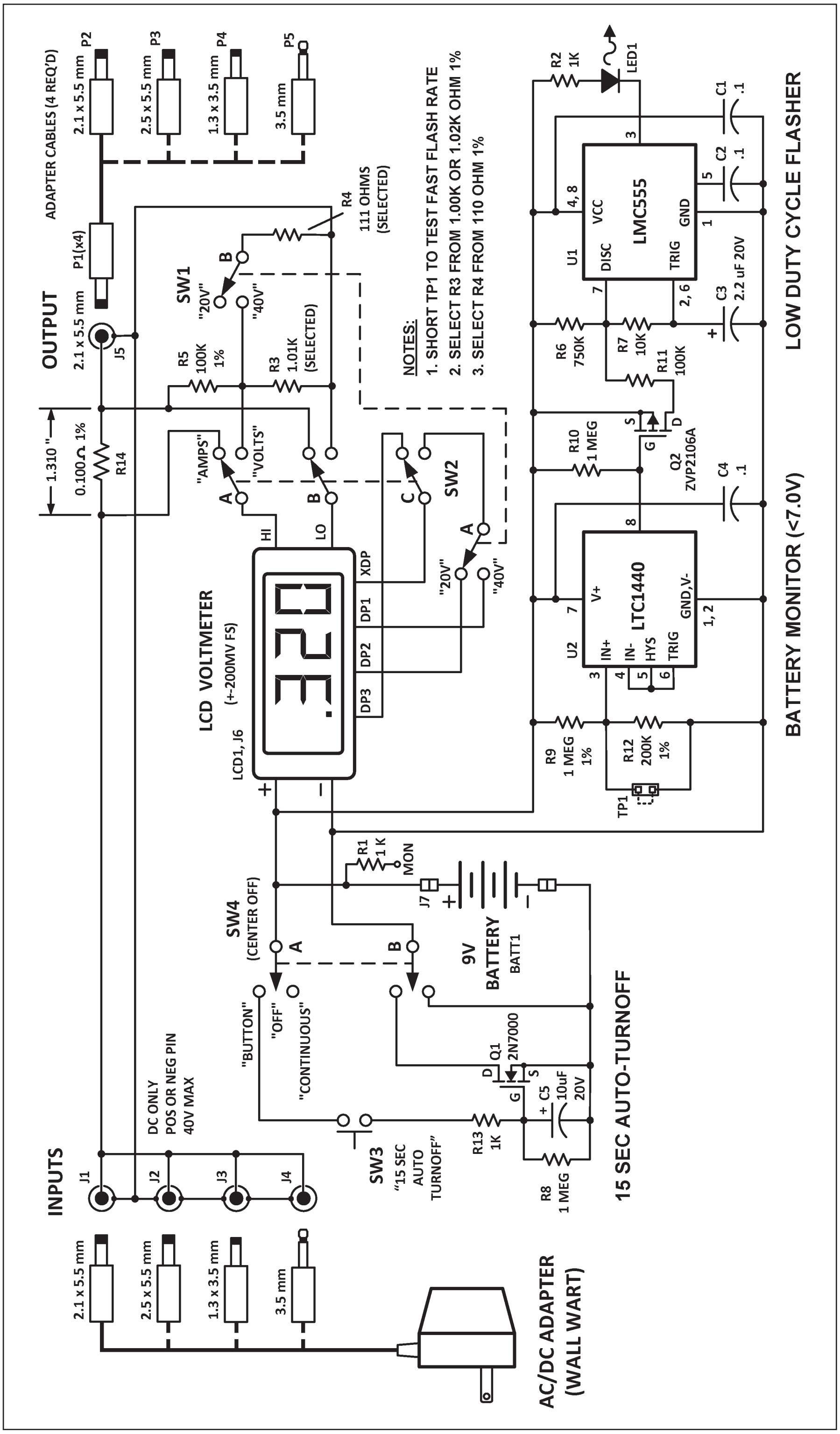
So, I poured over the catalogs looking for an isolated converter with just the right mix of specs. To make a long story short, the design became way too complicated. It looked like I would need to add a diode bridge (to handle positive and negative pins), pre-regulator, small heatsink, DC-DC converter, and raise the minimum input voltage to 5V. Too messy. The KISS principle won the day. Battery power was the best choice!

Bells and Whistles

Just when I thought the design was pinned down, I realized there were times when I wanted to leave the monitor on for a half hour or so, not just 15 seconds. For example, when I'm checking out a GPS module. So, I added a new switch for "continuous" operation, designated as SW4 in **Figure 3**. I chose a center-off switch so if the monitor was not going to be used for an extended period, the battery could be totally disconnected.

However, the "continuous" feature presented a new problem. The monitor could inadvertently be left on and I would never know it except for the dim LCD readout. So, I added one of the "desired" features: an LED. But wait! LEDs draw too much current, you say!

■ **FIGURE 3.** Schematic of the monitor features, auto-turnoff, battery monitor, and LED flasher circuits.



To counter that, I changed the design to a low duty-cycle blinking LED. I considered using a 2N6028 PUT or a CMOS LMC555 to generate the pulses. They both consumed about the same amount of current — 200 µA — but the 555 would be easier to control. R6 and R7 were selected so the rate would be ~1 Hz with a duty cycle of 2%. The average current for the LED would be around 100 µA. Perfect.

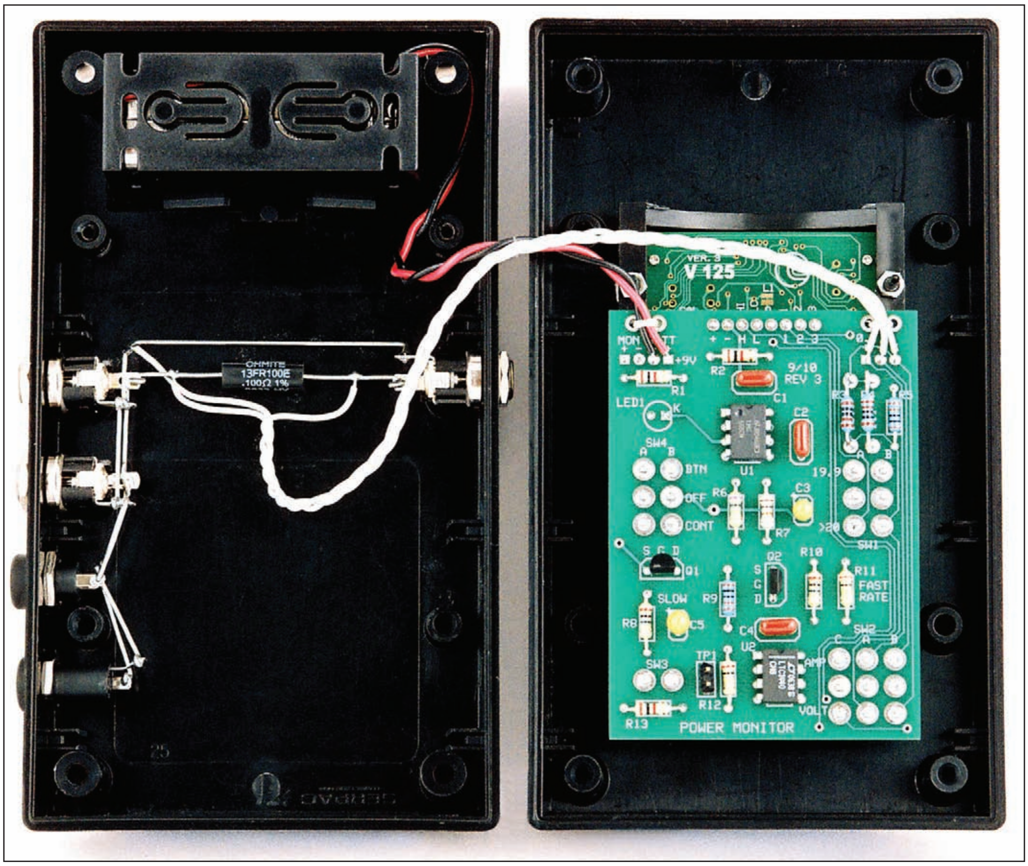
The next challenge was to add a battery monitor so the user would know when to change the battery. I wired up a low-power (4 µA) LTC1440 comparator on the test breadboard and selected R9 and R12 to switch at ~7.0V. The formula is Vthresh = 1.182*((R9+R12)/R12). Now, here's the really cool part. Instead of adding yet another LED, I tried to make the comparator increase the flash rate of the existing LED to indicate a low battery.

Again, more additions — R10, Q2, and R11. When the battery drops below 7.0V, the LTC1440 output goes low, turning on the P-channel FET which puts the 100K (R11) in parallel with R6, and raises the rate up to about 5 Hz. Bottom line: 1 Hz = Unit on; 5 Hz = Change the battery.

Even with all these bells and whistles added to the breadboard, the final measured average drain on the battery was only 1,250 µA. Acceptable!

Lastly, I added a "range" switch (SW1) to handle wall warts over 20V. SW1 changes the voltage divider — R5 and R3 — from 100:1 to 1,000:1. Now, the meter reads either 0-19.99V or 0-199.9V. Changing the decimal points was easy too; just add an extra pole to SW1 and SW2.

There was still a question in my mind regarding the best way to label the new range switch. Should it be 20V and 200V, like a conventional digital multimeter, or something else? I hesitated to use the 200V label because the monitor was designed to measure a maximum of 24V — not



■ **FIGURE 4.** Interior view shows battery box, 0.100 ohm current sense resistor, and the PCB.

high voltages. So, I settled on 20V and 40V. Plus, I added a label — "40V MAX" — near the input connectors to specify the upper limit.

Construction

Okay. Now that the design was frozen, it was time to package it. In the Digi-Key catalog, I selected a wrinkle-finish black Serpac SR251 enclosure because it had an internal battery box and plenty of room for all the switches and their labels. Then, I drilled the holes, applied the white rubdown letters, and sprayed it with Krylon Matte Finish #1311. DISASTER! The finish looked terrible — all mottled and uneven. I was sick. I checked the spray can. It definitely was compatible with plastics and had worked on other projects in the past. What was going on?

Fortunately, I had another Serpac SR251 box so I started all over again, new holes, new lettering. What a pain! Then, I took an old spare Serpac box and sprayed it with three different plastic-compatible Krylon sprays: Matte Finish #1311, Low Odor Clear Finish (Matte), and Low Odor Clear Finish (Gloss). The Low Odor Clear Finish (Matte) looked the best, so that's what I used on the box shown in **Figure 2**. However, please do your own tests before using any of these sprays on your next project.

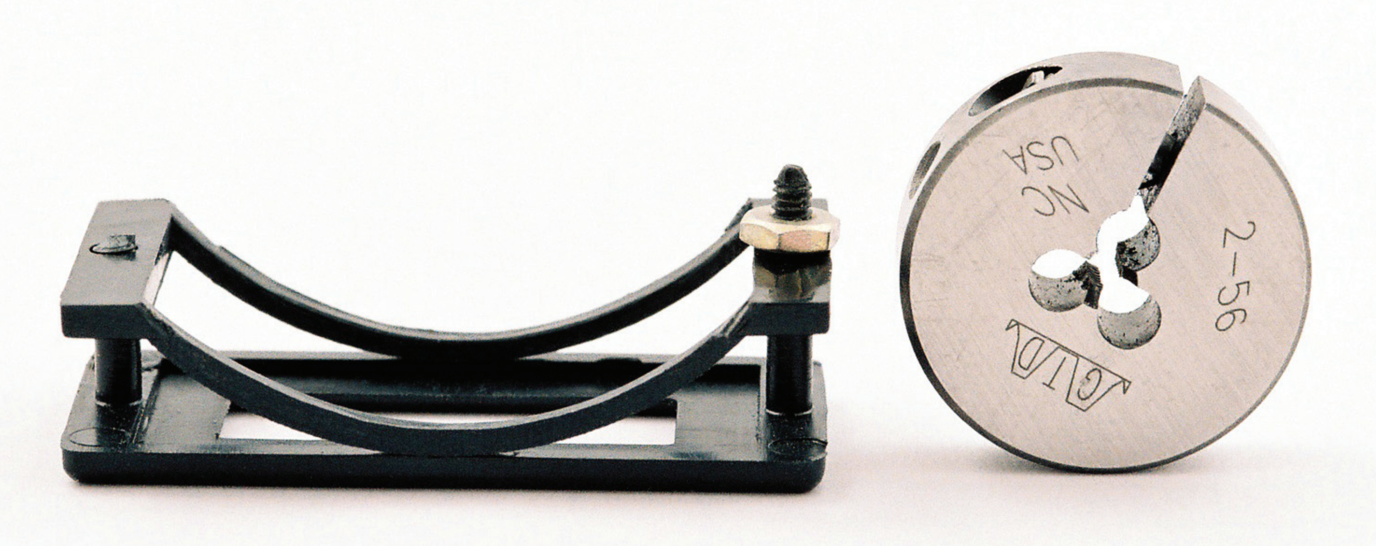
As for the PCB, I considered using surface-mount components, but there was plenty of room between the switches for through-hole parts, as illustrated in **Figure 4**. I included a test point (TP1) so the low battery condition could be tested.

SPECIAL NOTE: It is important that the wires soldered to the current sense resistor, R14, are connected at a spacing of 1.310", as per the spec sheet. This assures the accuracy of its value, 0.100 ohms +-1%.

As much as I like the Martel V-Series

PARTS LIST

ITEM	DESCRIPTION	DIGI-KEY (unless noted otherwise)
C1,C2,C4	0.1 µF, 50V, Bypass	P4525-ND
C3	2.2 µF, 20V, Tant	478-1869-ND
C5	10 µF, 20V, Tant	478-1840-ND
1% RESIS	Metal Film, 1%, 1/4W	value+XBK-ND
OTHER RES	Carbon Film, 5%, 1/4W	value+QBK-ND
R14	0.100 ohms, 1%, 3W	13FR100E-ND
Q1	2N7000, N-chan MOSFET	2N7000FS-ND
Q2	ZVP2106A, P-chan MOSFET	ZVP2106A-ND
U1	LMC555 Timer	LMC555CN-ND
U2	LTC1440 Comparator	LTC1440CN8#PBF-ND
SW1	DPDT, Toggle	EG2400-ND
SW2	3PDT, Toggle	EG2425-ND
SW3	SPST Pushbutton, N.O.	Mouser, 10PA322
SW4	DPDT, Center-Off, Toggle	EG2414-ND
J1,J5	2.1 x 5.5 mm Panel Jack	SC1049-ND
J2	2.5 x 5.5 mm Panel Jack	SC1048-ND
J3	1.3 x 3.4 mm Panel Jack	Mouser, 163-4015-EX
J4	3.5 mm Panel Jack	Mouser, 161-1640-EX
J6	8 pos LCD Socket, 0.1"	S4108-ND
J7	9V Battery Connector	Mouser, 121-1026T-GR
P1(4),P2	2.1 x 5.5 mm Plug (5)	SC1052-ND
P3	2.5 x 5.5 mm Plug	SC1051-ND
P4	1.3 x 3.5 mm Plug	CP3-1003-ND
P5	3.5 mm Plug	CP3-1005-ND
LCD1	LCD Voltmeter, 0.5"digits	227-1060-ND
LED1	LED, Red	67-1066-ND
PCB	PCB w/Mask & Silkscreen	ExpressPCB
BOX	Serpac, w/Batt Box, Black	SR251B-ND
LETTERS	White Ltrs&Nums, 4 sizes	FLS Discount #681012



■ **FIGURE 5.** Threading die allows the LCD bezel to be secured with 2-56 nuts.

voltmeters, they have a flaky mounting scheme. **Figure 5** is a close-up of the front bezel. It has two plastic mounting posts that accept push-on fasteners. I broke off one of the posts as I struggled to push on the first fastener. It was my fault, but there had to be a better way.

The solution was simple: Buy a 2-56 threading die from McMaster-Carr. The diameter of the posts just happens to be real close to a 2-56 screw. By carefully threading the posts, you can use 2-56 nuts to secure the LCD. Sweet!

Using a digital ohmmeter, I selected the non-

REFERENCES

www.martelmeters.com/pdf/V_125.pdf

www1.duracell.com/oem/Pdf/Mn1604.pdf

www.ohmite.com/catalog/pdf/10_series.pdf standard voltage-divider resistors, R3 and R4, from a pile of 1K and 110 ohm resistors. Then, I soldered them on the PCB, along with all the other components and the LCD connector. R1 was only used during development so it may be omitted.

Testing

Next, I plugged the unmounted LCD into the PCB and did a thorough electrical check of every function, using clip leads to simulate the switches. When I was confident that everything was working, I mounted the LCD in the case, soldered the PCB to the switches, and connected the wires from the battery and sense resistor.

Finally, I briefly shorted TP1 to test the low battery 5 Hz fast rate, then closed the case and put in the four screws. Done at last. Eagerly, I plugged a wall wart into the appropriate input jack and the output plug into a Parallax BOE Board. It read 7.66 volts at 88 milliamps. Success!

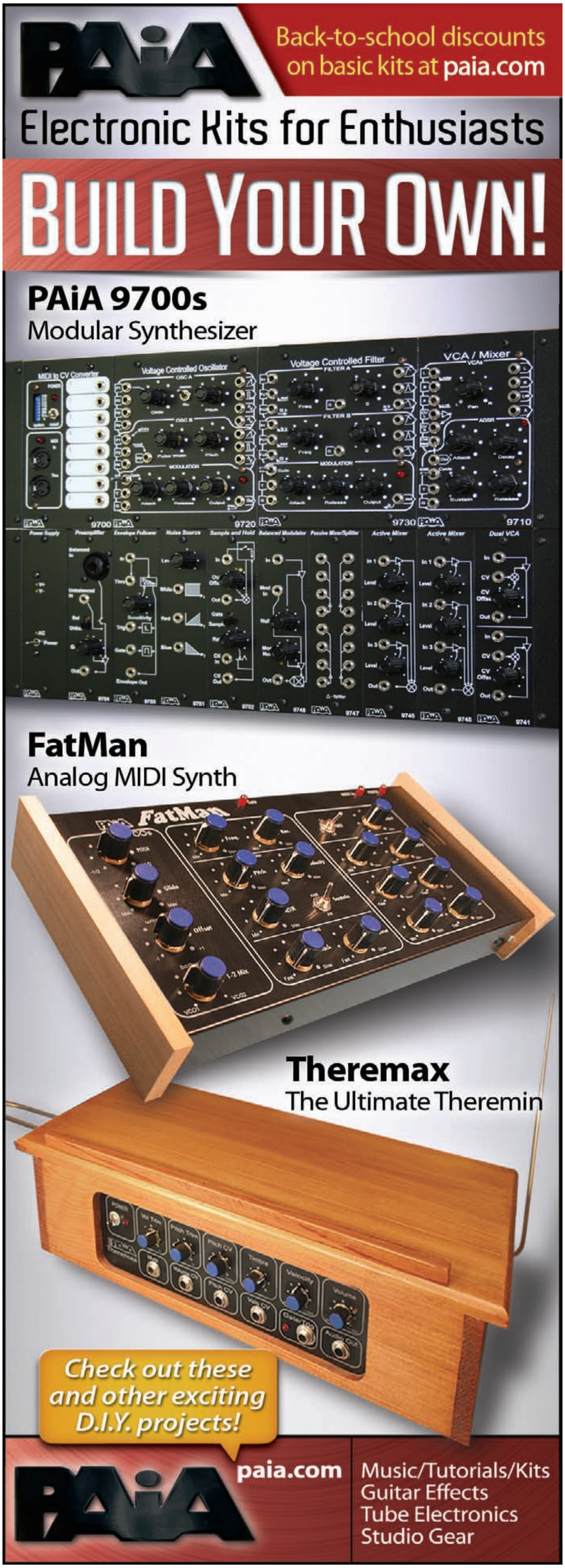
Final Word

I've been using the Wall Wart Power Monitor for several months now, and it works great. It's been a fun and useful project for me. I think you'll find it useful too.

For the Next Model

If the input and output connectors were changed to the board-edge mounted type, then all the connectors and the 0.100 ohm resistor could be mounted on the PCB, making a cleaner design.

Here's an outside-of-the-box idea. How about using solar power from the room lights to supply the 1 mA for the LCD? **NV**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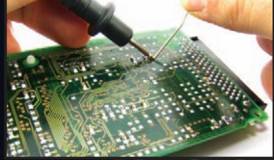

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- PCB and all electronic components included

"Pre-Champ" Versatile Preamplifier

KC-5166 $6.50 plus postage & packing

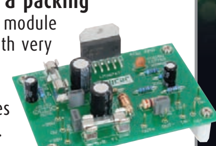
This tiny preamp was specifically designed to be used with the 'Champ' amplifier KC-5152. Unless you have a signal of sufficient amplitude the 'Champ' will not produce its maximum power output. The 'Pre-Champ' is the answer with a gain in excess of 40dB, which is more than enough for most applications. You can vary the gain by changing a resistor and there is even provision on the PCB for an electret microphone. Use AM-4010 $2.00.

- Power requirement 6-12VDC.
- Kit includes PCB and electronic components
- Can be battery powered

50 Watt Amplifier Module

KC-5150 $22.00 plus postage & packing

This 50 watt unit uses a single chip module and provides 50WRMS @ 8 ohms with very low distortion. PC Board and electronic components supplied. PC Board size only 84 x 58mm. Requires heatsink. See website for full specs.

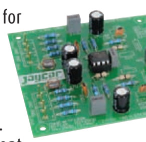


- Heatsink to suit HH-8590 $12.50

Universal Stereo Preamplifier

KC-5159 $12.50 plus postage & packing

Based around the low noise LM833 dual op-amp IC, this preamp is designed for use with a magnetic cartridge, cassette deck or dynamic microphone. The performance of this design is far better than most preamps in many stereo amplifiers, making it a worthy replacement if your current preamp falls short of expectation. It features RIAA/IEC equalization, and is supplied with all components to build either the phono, tape or microphone version.

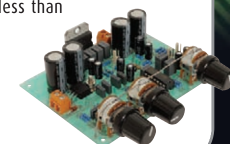


- Measuring only 80x78x30mm, it is ideal for incorporating into existing equipment and is hence supplied short form of PCB and specified components plus PCB standoffs for mounting.
- +/- 15VDC required, use KC-5038 $11.00.
- If power is not available in your equipment use MM-2007 $5.50.

HIGH PERFORMANCE 12V STEREO AMPLIFIER

KC-5495 $32.75 plus postage & packing

An ideal project for anyone wanting a compact and portable stereo amp where 12V power is available. No mains voltages, so it's safe as a beginner's first amp. Performance is excellent with 20WRMS per channel at 14.4V into 4 ohms and THD of less than 0.03%. Shortform kit only.



- Kit includes PCB & on-board electronic components
- 12VDC
- Recommended heatsink Cat No. HH-8570 $4.50

CLIFFORD THE CRICKET

KC-5178 $12.50 plus postage & packing

Clifford is created on a small PCB, measuring just 40 x 35mm and has cute little LED insect eyes that flash as it sings. Just like a real cricket, it waits a few seconds after darkness until it begins chirping, and stops instantly when a light comes back on.

- PCB, piezo buzzer, LDR plus all electronic components supplied

KIT OF THE MONTH

Hearing Loop Receiver Kit

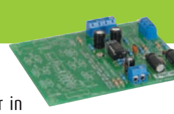
KC-5497 $22.00 plus postage & packing

A hearing loop is an inductive assisted listening system for the hearing impaired. They're typically installed in venues such as churches and conference rooms to enable listeners to receive in-ear communication via a wireless induction loop. You can now install this technology on your own TV, home theatre or hi-fi system. This will enable someone who's hard of hearing to hear at their own volume level without having to turn the volume up to a level too high for everyone else. The receiver will drive a pair of headphone or earbuds from the signal picked up from the hearing loop. The whole unit is completely self-contained and can be carried around in a pocket or you can add your own belt clip, so the user isn't constrained by a set of headphone leads. The kit is complete with case, label, PCB and components.

Note: Transmitter not included

- Current consumption: 10mA
- Frequency response: 100Hz - 5kHz
- S/N ratio: 67dB
- Battery voltage indication: Down to 7V

BRIDGE MODE ADAPTOR FOR STEREO AMPLIFIER



KC-5469 $20.25 plus postage & packing

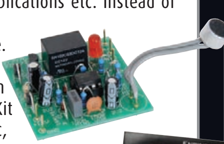
Enables you to run a stereo amplifier in 'Bridged Mode' to effectively double the power available to drive a single speaker. There are no modifications required on the amplifier and the signal processing is done by this clever kit. Supplied with silk screened PCB and components. Requires balanced (+/-) power supply.

- PCB: 103 x 85mm

"MINIVOX" VOICE OPERATED RELAY

KC-5172 $12.00 plus postage & packing

Voice operated relays are used for 'hands free' radio communications and some PA applications etc. Instead of pushing a button, this device is activated by the sound of a voice. This tiny kit fits in the tightest spaces and has almost no turn-on delay. 12VDC @ 35mA required. Kit is supplied with PCB, electret mic, and all specified components.



- PCB: 47 x 44mm

THE SUPER EAR

KA-1809 $20.25 plus postage & packing

Assists people who have difficulty hearing high audio frequencies, or use as an interesting education aid in the classroom. By amplifying high audio frequencies, conversations will be made clearer and you will hear sounds not normally heard such as insects or a watch ticking. Kit supplied with case, processed panels, PCB, 9V battery, and all electronic components. Headphones required.

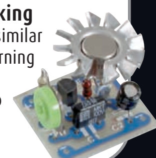
- PCB: 56 x 26mm

Note: Not a replacement for a proper hearing aid.

FOG HORN

KG-9092 $9.50 plus postage & packing

This kit generates a deep sounding noise similar to fog horns on ships. Use as a unique warning siren or to improve a child's toy. Operating voltage is 4.5V to 12VDC. Output power up to 5 watts depending on the input voltage used. Requires an 8 ohm speaker.



RADIO KITS

Miniature FM Transmitter

KE-4711 $9.75 plus postage & packing

This unit is a two transistor two stage transmitter that has the benefits of being VERY COMPACT. Kit contains PCB, 9V battery and all components, and makes an ideal, inexpensive beginners kit.

- PCB - 45 x 22mm • 9VDC

100-200MHz VHF Converter

KG-9128 $22.00 plus postage & packing

This simple to build kit makes it feasible to receive, for example, taxis, amateur radio operators, marine radio, television audio carriers, etc. The kit connects in-line with your VHF receiver's antenna avoiding messy installation and receiver modifications.

- Operating voltage 9V DC

POST & PACKING CHARGES

Order Value	Cost
$25 - $49.99	$7.50
$50 - $99.99	$20
$100 - $199.99	$40
$200 - $499.99	$60
$500+	$75

Max weight 12lb (5kg).
Heavier parcels POA.
Minimum order $25.

Note: Products are dispatched from Australia, so local customs duty & taxes may apply.
Prices valid until 28/2/2011

HOW TO ORDER

WEB: www.jaycar.com
PHONE: 1-800-784-0263*
FAX: +61 2 8832 3118*
EMAIL: techstore@jaycar.com
POST: P.O. Box 107, Rydalmere NSW 2116 Australia

- ALL PRICING IN US DOLLARS
- MINIMUM ORDER ONLY $25

*Australian Eastern Standard Time
(Monday - Friday 09.00 to 17.30 GMT + 10 hours)
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avrtoolbox — Open Source And Version Control

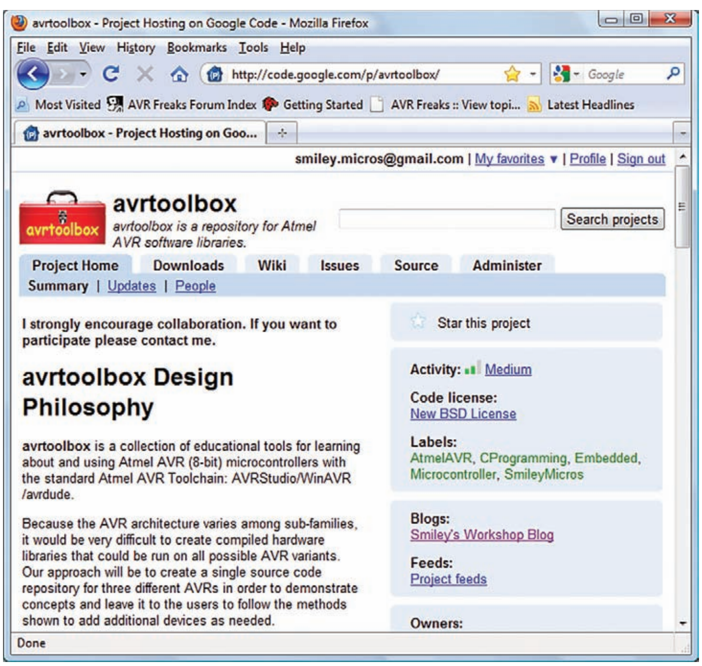
Follow along with this series! Joe's book & kits are available at www.nutsvolts.com

by Joe Pardue

Recap

Last month, we started work on the avrtoolbox to help us keep Smiley's Workshop a bit tidier by providing a clean and orderly place to put stuff. We learned how to document our code with Doxygen and how to keep track of all those functions lying around by putting them in libraries.

This month, we are going to learn how to create an open source project using Google Code and keep track of all the different versions of the code we are writing using TortoiseSVN — both using the avrtoolbox as an example. I started off calling this series AVR_Toolbox, but since Google Code won't accept caps I'm officially changing the name to all lowercase without the under bar. It is now simply avrtoolbox.



■ FIGURE 1. avrtoolbox Open Source Project.

Open Source — The Next Big Thing?

Open source is everywhere! It's the next big thing! Millions of people are being helped and millions of dollars are being made! Salvation is at hand! You know the story: A bunch of highly caffeinated nerdy guys get obsessed with the latest technology that is going to change the world as we know it. They search out free 'open source' information that tells them how to do it themselves. They borrow a friend's shed, collect tools, and burn a lot of midnight oil hacking away at this next big thing. Soon their labors come to fruition and out rolls a world changing innovation ... Linux? Arduino? Combat robots? So where in 2010 is this happening? Well folks, that's the wrong century by two. It's the 1890s and the nerds in question used the magazine *American Machinist* to get a free 'open source' design for an internal combustion engine. The lead hacker: Henry Ford. And out rolls his quadracycle.

From the hyperventilating Internet articles I've been reading lately, you'd think that open source is both new and world changing (if you believe some blogs), but it is, in fact, the next old thing being rediscovered. *Nuts & Volts* has been doing open source and giving it away for years, in a long tradition that goes back to Hugo Gernsback importing radio components and showing folks how to use them in the 1908 magazine *Modern Electrics*. So, is there any difference in what is happening today? Yes — information velocity.

In the good old days, if you had a question and if one of your friends didn't know and you couldn't find the answer in your pile of magazines or the library, you had to compose a letter to someone who might know the answer and wait for snail mail to get your hoped-for response. Today, you just log onto an Internet forum, ask your question, and almost instantly get a response (often RTFM or something similarly snarky). Another big difference is your circle of 'friends'. Henry Ford was pretty much limited to his neighbors in Detroit, but with the Internet I now have friends all over the planet who can help me figure stuff out.

Another big difference is cost. This is both a blessing and a curse. The marginal cost of reproduction on the Internet is near enough to zero that it can be neglected. This magazine you are holding in your sweaty hands costs money to print, but if you get the article in an electronic format it doesn't cost the publisher as much to send it to you. Here's the downside: Since putting information on the Internet is so cheap that any idiot can afford to do it, many idiots do it. How do you know that something you found with Google is accurate? You don't really.

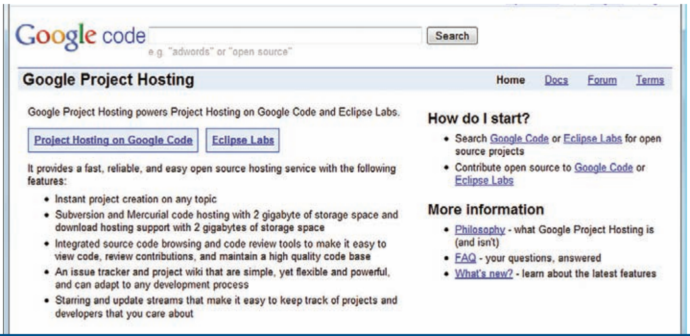
At least with a paper magazine or book there is cost involved so somebody might have spent some time vetting the material. That doesn't mean dead tree resources are always correct, however. I've made my share of paper and ink blunders, but some of the crap I've seen on the Internet makes me wonder if the stuff wasn't posted intentionally to mislead. Which brings us to the worst aspect of the Internet: trolls. (Don't get me started.)

Even with the lack of reliable filters, the Internet is still the best information sharing tool ever invented. So, I'm going to share some of the stuff I've been writing about by putting it in an open source project: avrtoolbox on Google Code. I put the above section on AVRfreaks for comments and, oh yes, I got some (**http://tinyurl.com/393y8fc**). If you aren't familiar with **tinyurl.com**, it's a free service that provides an alias for long URLs like the ones usually generated by forum posts.

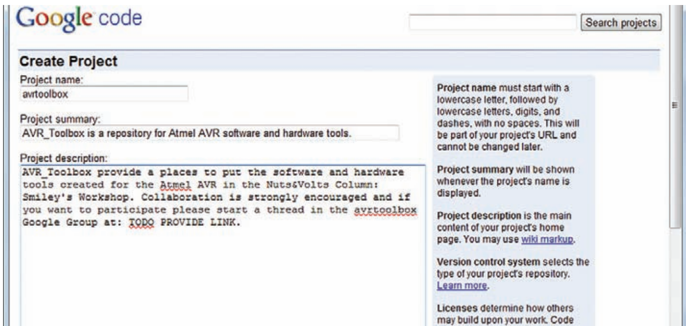
Open Source Licenses Are A Sign Of Mental Illness

Open source means free, doesn't it? Maybe, but I've been baffled by all the guff I've read about software licenses. What does "free" mean anyway? I believe nobody reads the lawyer BS, so this is what I used to put at the head of all my code: *If you use this software, it will destroy whatever machine you use it on and kill anyone in a one kilometer radius. So, don't even consider using it for any reason whatsoever! Have a nice day.*

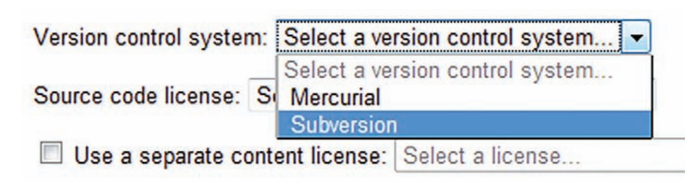
I thought that by not having a license, the code was free to use, and that by joking about destruction no sane person would think to sue me if the code wasn't perfect. Then, someone informed me that by *not* having a license on my source code I was actually copyrighting my code and other folks couldn't legally use it. Apparently, the restrictive copyright comes with the creation, so you have to explicitly reject the standard copyright and use a license to let other folks use your materials. So, I read a bit about licenses and found some of the most esoteric philosobabble discussions by people who truly have too much time on their hands. After hours of reading about what 'free' really means, I decided these guys are freaking



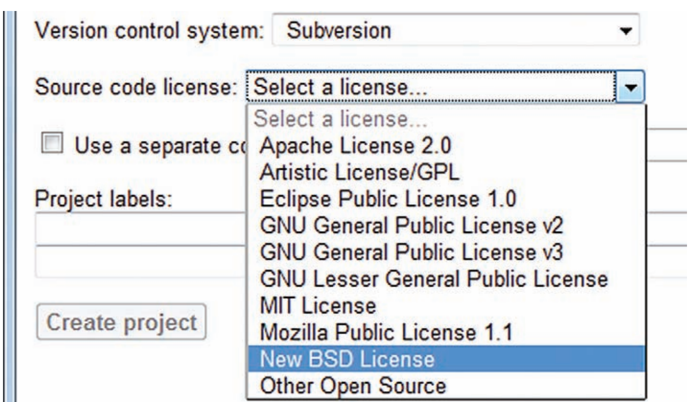
■ FIGURE 2. Google Code Project Hosting.



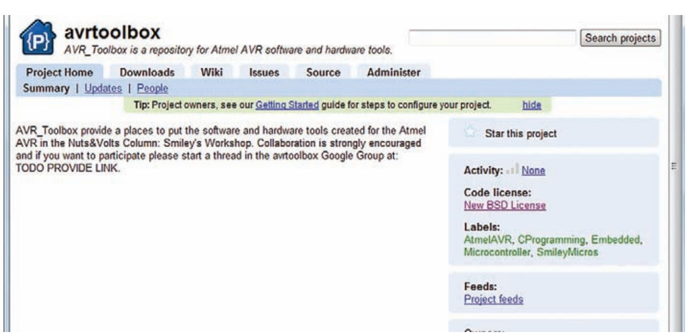
■ FIGURE 3. Google Code Create Project.



■ FIGURE 4. Google Code Select Version Control System.



■ FIGURE 5. Google Code Select License.



■ FIGURE 6. Google Code avrtoolbox Project.

crazy. I couldn't pick a license. Thankfully, I stumbled across Google Code which says this: "*The open source community has been flooded with lots of nearly identical licenses. We'd like to see projects standardize on the most popular, time-tested ones. The selected licenses offer diversity to meet most developer needs.*" Then, instead of allowing hundreds of choices, they only allow nine [only?]. I selected the 'New BSD License' because someone I trust who is nominally sane said it was the least restrictive.

I posted this section on AVRFreaks and started a thread that turned immediately into an 'esoteric philosobabble' discussion (**http://tinyurl.com/27s3y37**).

Collaborative Open Projects

Then there is the silliness of open source hardware. Excuse me, but 'source' refers to 'source code.' The open hardware folks get into discussions of source that rival those on the meaning of free. So, I'm going to settle this for me by using COP — Collaborative Open Projects — to refer to anything where folks collaborate on a project and intend the documentation to be free (as in no money and no lawyers). Like everything else Internet, there are a buzzillion ways to have a COP. I've chosen Google Code which may not be the best but it seems the simplest to me, and I need simple.

Google Code

There are some great free software development tools available on the Internet. In fact, *some* is an understatement. There are so darn many tools that (like licenses) it is nearly impossible to decide what is best for any particular purpose. I decided that I wanted to collaborate with folks on open source projects, but I didn't have much of a clue where to start. I spent a few days digging around and finally decided that I wouldn't be able to declare any 'best' way to do this. So, without saying that I've found the best free solution, I will say I've found a good set of tools and am beginning to learn how to use them.

Remote Open Source Code Repository

As I've stated, I chose Google Code. Why didn't I choose SourceForge or github or some other website? Mainly because the Google Code site looks simple and clean. Also, after reading some stuff on the Google Code website, I saw that they are restricting choices to the most commonly used sorts of things. Now one might be opposed to having restricted choice (freedom and all that), but when you're learning, a little guided restriction can be a blessing. I have to trust that Google is being reasonable in winnowing the choices consistent with the goals.

The first objection I'm going to hear about from you is that Google Code requires you to register. So, this doesn't mean they are going to steal all your personal information and send it to that son of a recently deceased government official in Nigeria who wants you to help him transfer $12 million to the US. Enough making fun already – just sign up with Google or go away and do your own thing.

Google Code Create Project Recipe

I presume you'll create your own project and put it under version control to learn these skills. I recommend patience since I did this three times and had some difficulties each time (including losing my freaking password). Let's learn how to start an open source project and do it cookbook style. Go to **http://code.google.com/projecthosting**/. Click 'Project Hosting on Google Code' shown in **Figure 2**.

- Click 'Sign in to create a project.'
- Click 'Create a new project' and fill in the project information as shown in **Figure 3**. Note that the project name must be all lowercase and cannot have certain characters. For example, it wouldn't take Avr_Toolbox but did take avrtoolbox. (Possibly somebody at Google forgot what century we're in?)
- Click on 'Version control system:' as in **Figure 4**.
- Click on 'Source code license:' as in **Figure 5**.

So, now we have **Figure 6**.

Version Control — It's A Time Machine

A version control system manages files and directories, and the changes made to them over time. It allows you to recover your older work and track the history of the changes you've made. When you smack your head over something really stupid you've been doing for a few days, you'll be glad you have a version control system time machine to take you back to your last intelligent moment so you can examine the details of when you messed up. If you are like me, you'll just revert to that moment and trash the rest. However, with a version control system, you don't actually trash anything so if you decide that your stupid period maybe wasn't so stupid after all, you can recover those bits.

Another really useful feature is that a version control system allows several folks to work on the same stuff at the same time without risking destroying each other's work. If you and I check out the same thing and each make a change, the system will tell us to have a discussion about it before it will let either of us put it into the system.

If you've never used a version control system before, you'll need to learn some of the lingo so that you can talk the talk. To save space, I'll recommend that you mark this spot and then proceed to the Internet book: *Version Control with Subversion*, Chapter 1. Fundamental Concepts (**http://svnbook.red-bean.com/en/1.5/svn.basic.html**). They do a great job so there's no reason to repeat it here. I do suggest you mark this spot when you finish that chapter since the rest of the book can get a bit hairy without a guide. Let's set up a real version control system for our avrtoolbox project.

TortoiseSVN And Our Project Directories

You can get your free copy of TortiseSVN at **http://tortoisesvn.tigris.org**/. Follow their instructions to get it installed on your PC. Let's start by creating a directory tree so we'll have something to put under version control. I decided on (see **Figure 7**):

- avrtoolbox
  - AVR_Applications
  - Documentation
  - Libraries
    - Elementary
    - General
    - Drivers

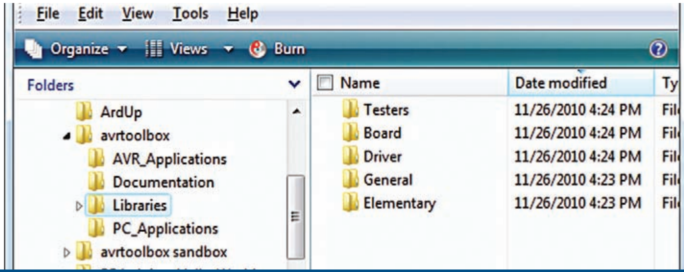


FIGURE 7. avrtoolbox in Windows Explorer.

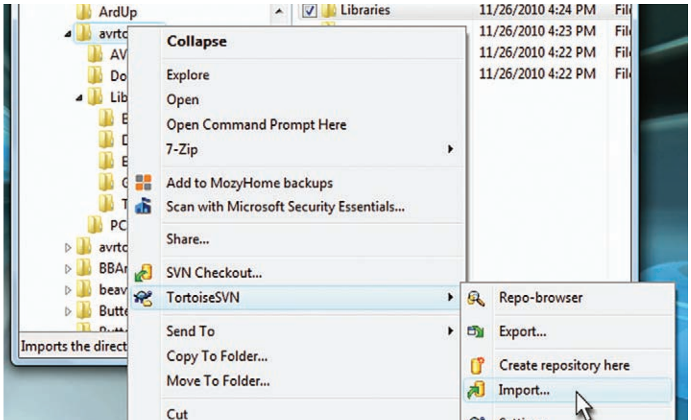


FIGURE 8. Right-click avrtoolbox and Select TortoiseSVN Import.

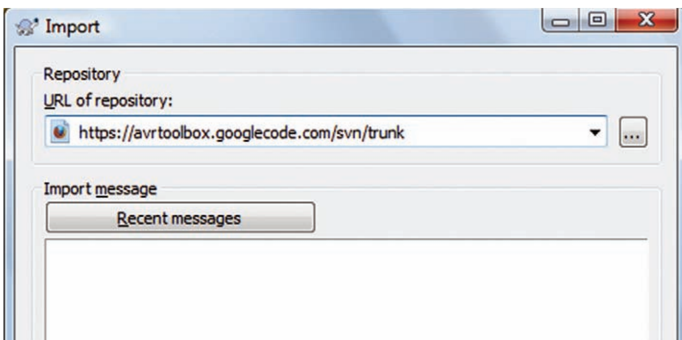


FIGURE 9. Import to Repository.

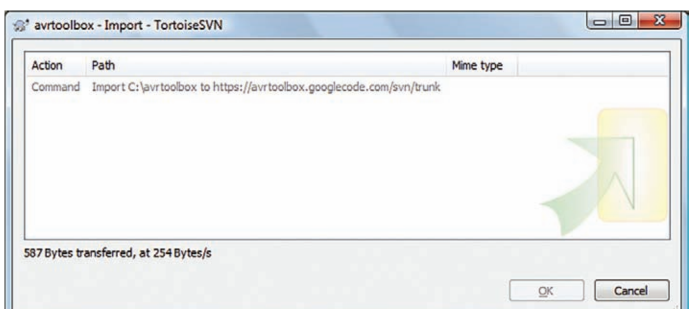
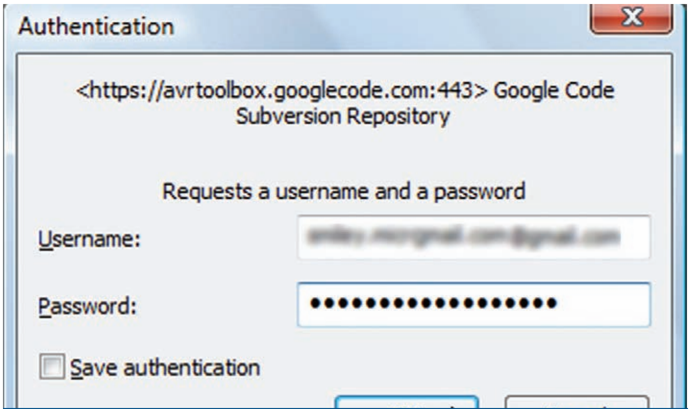
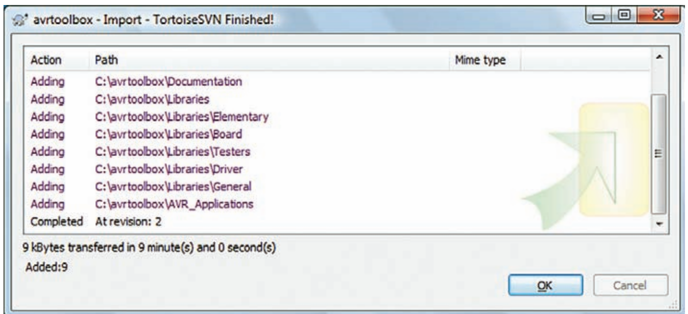


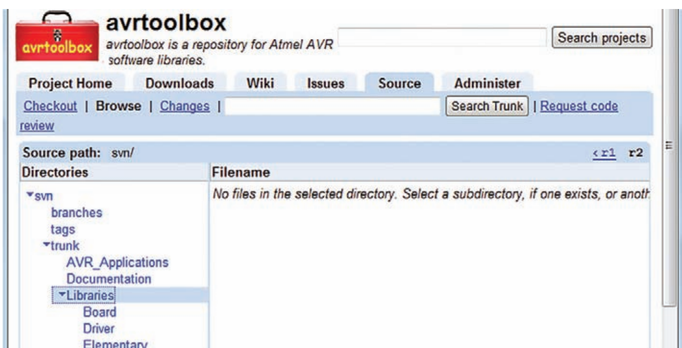
FIGURE 10. TortoiseSVN Import.



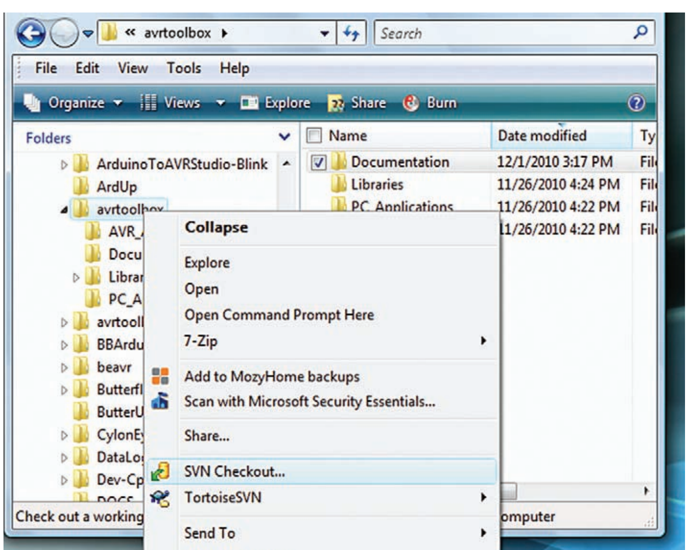
■ FIGURE 11. TortoiseSVN Authentication.



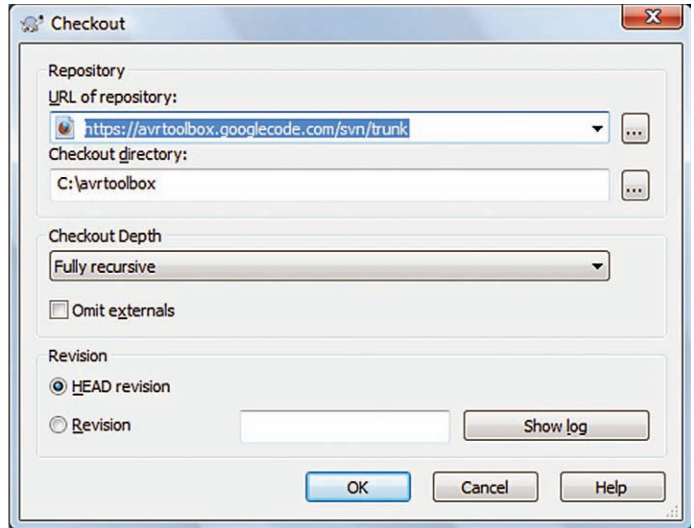
■ FIGURE 12. TortoiseSVN Finished Importing.



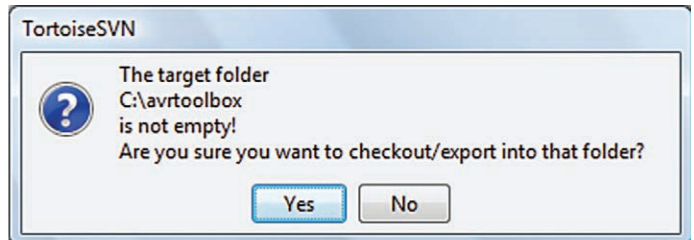
■ FIGURE 13. Google Code SVN Directory Tree.



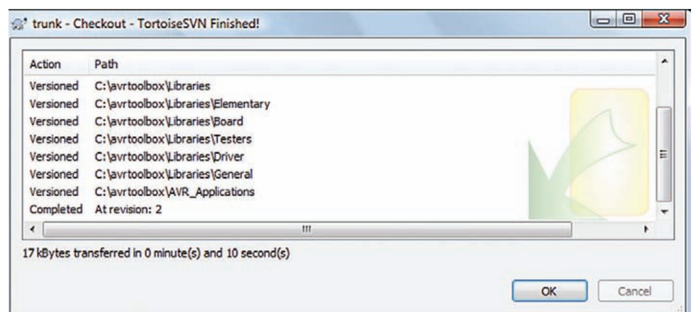
■ FIGURE 14. SVN Checkout.



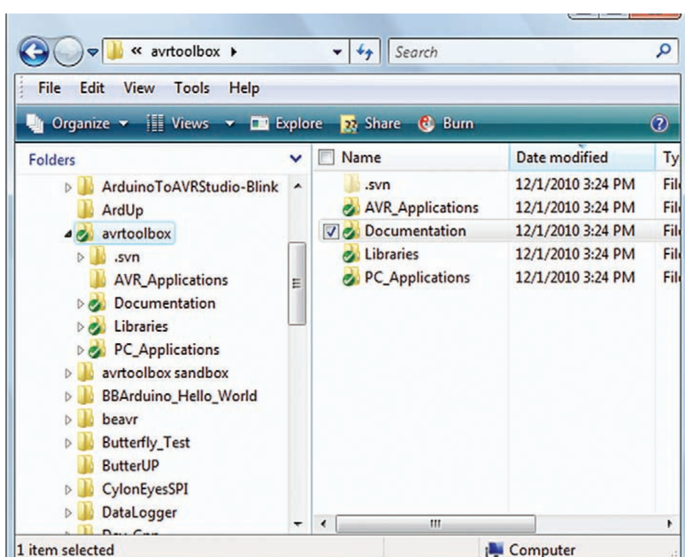
■ FIGURE 15. TortoiseSVN Checkout.



■ FIGURE 16. Are you sure? Duh, yeah!



■ FIGURE 17. TortoiseSVN Finished.



■ FIGURE 18. TortoiseSVN Checkout Successful.

        - Board
        - Testers
    - PC_Applications

Make sure you are attached to the Internet, then right-click on the avrtoolbox directory and select the TortoiseSVN import as shown in **Figure 8**. This is very non-intuitive since what you are really doing is uploading the directory tree to your Google Code project; from the perspective of that project, you are 'importing' those directories from a PC out in space somewhere. You are at your PC but your repository is at Google somewhere. That's the perspective taken by TortoiseSVN. This will open the window shown in **Figure 9**. Click OK and you'll see the window in **Figure 10**. Next, you'll see the Authentication window shown in **Figure 11**. Be sure and remember that the password requested is specific to the Google Code project you created and is NOT the same as your general Google password. This bit me a few times. Click OK and you'll see **Figure 12**.

Now, go to the avrtoolbox project on Google Code and click on the Source tab and the Browse button; you'll see **Figure 13** which verifies that you've successfully imported the directories.

Example Of Version Control

After we get the directories on our Google Code project, we need to link them back to the directories we have on our PC. Right-click on the avrtoolbox directory in Windows Explorer and then click on SVN Checkout as shown in **Figure 14**. **Figures 15**, **16**, and **17** show the process for completing the Checkout. Now that you've got them checked out, TortoiseSVN puts a special green checkmark on the directories in Windows Explorer as in **Figure 18**.

Test It With A Text File

That was great, but now you have a bunch of empty directories. Let's put a text file in one so that we can see how our repository on the

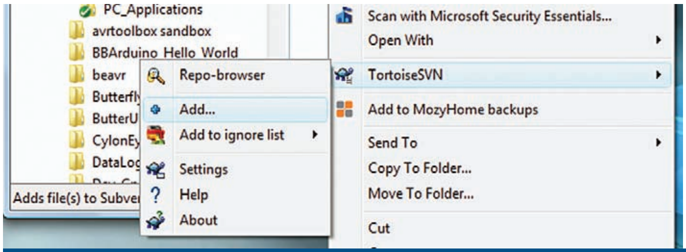


FIGURE 19. TortoiseSVN Add a File.

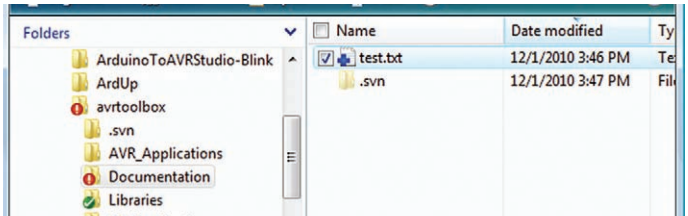


FIGURE 20. Directory Tree After File Added.

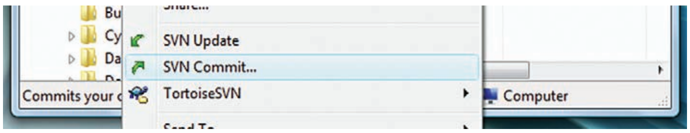


FIGURE 21. TortoiseSVN Select SVN Commit.

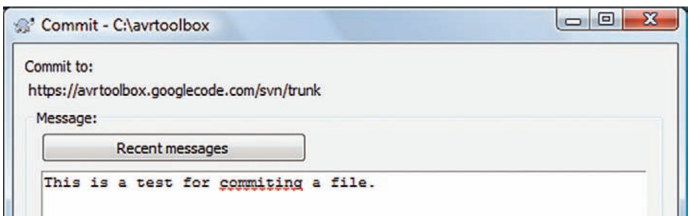


FIGURE 22. Tortoise SVN Commit (with spelling error!).

Internet cooperates with the directories we have on our PC. Let's create a simple test file in the Documentation directory: test.txt with the single line: 'This is a test of avrtoolbox.' We right-click on the file and then select Add ... as shown in **Figure 19**.

Now we see that the folder icons have changed as shown in **Figure 20**. The avrtoolbox and the Documentation directories have a red dot exclamation mark on them indicating that they are no longer in sync with the repository. To get them in sync, we right-click on the avrtoolbox directory and select SVN Commit as shown in **Figure 21**. This brings up a familiar window to which we add a comment about our file as shown in **Figure 22** (with spelling error!). This syncs the PC and the repository so we get **Figure 23**.

What Happens If We Change The File?

Let's add a sentence to our test.txt file: 'This line added to generate a changed file.' We get the red icons as in **Figure 24**. Only this time, one is added to the test.txt file. So, we repeat the stuff we did earlier. We right-click on test.txt, select TortoiseSVN Commit, and click our way through the process including signing in again, etc., to commit the newest version and change the icon back to green.

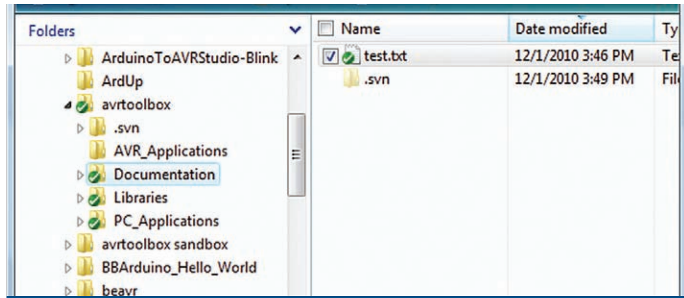


FIGURE 23. Greenlights all the way!

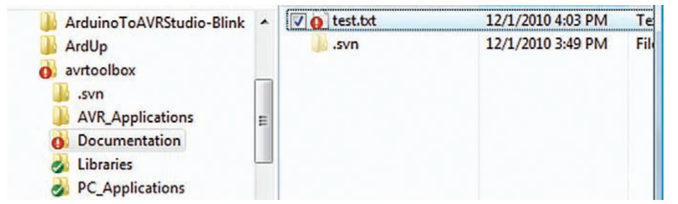


FIGURE 24. TortoiseSVN Test File Changed.

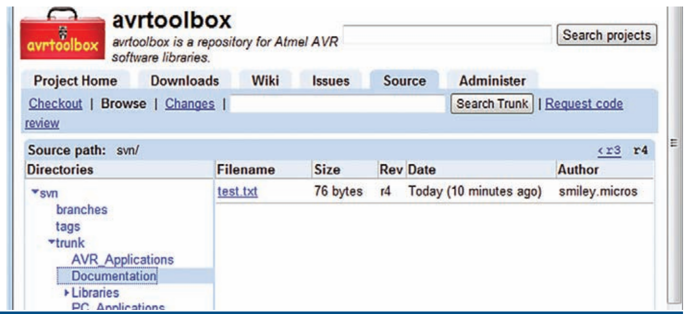


FIGURE 25. Google Code Test File in Directories.

So, What Do We Have Now In Google Code?

Let's look in our project directories in **Figure 25**. Now it's time to play with this a bit. Go to the Google Code project and click on things and see what happens. For instance, click on the test.txt file and you'll see not only the text in the file but the revision history.

This was a lot for one article. I'll be writing about many new AVR tools and putting the source code in our open source project. My hope is that some energetic folks will join in and help make this a really useful tool for the AVR community.

Let's Not Forget

The first thing you are going to forget is that the Google Code repository sign-in requires a different password than your Google account. Also, you will create directory paths with spaces or weird characters that avrdude won't take, so don't do that either.

Next month, we're going to bring all these organizing principles together and use them for a serial library. If you just can't wait and want to get a good leg up on C and the AVR while helping support your favorite magazine and technical writer, then buy my C Programming book and Butterfly projects kit from the *Nuts & Volts* website. **NV**

INTRODUCING

THE 32-BIT MICRO EXPERIMENTER

BY THOMAS KIBALO

In 2010, *Nuts & Volts* introduced the 16-bit Micro Experimenter with a seven article series. The 16-bit Experimenter offered a new and significant microcontroller capability when compared with current offerings of eight-bit technologies in both performance and functionality. This year, we're going to raise the bar with an even more powerful device — the "32-bit Micro Experimenter" or, as always, "Experimenter" for short.

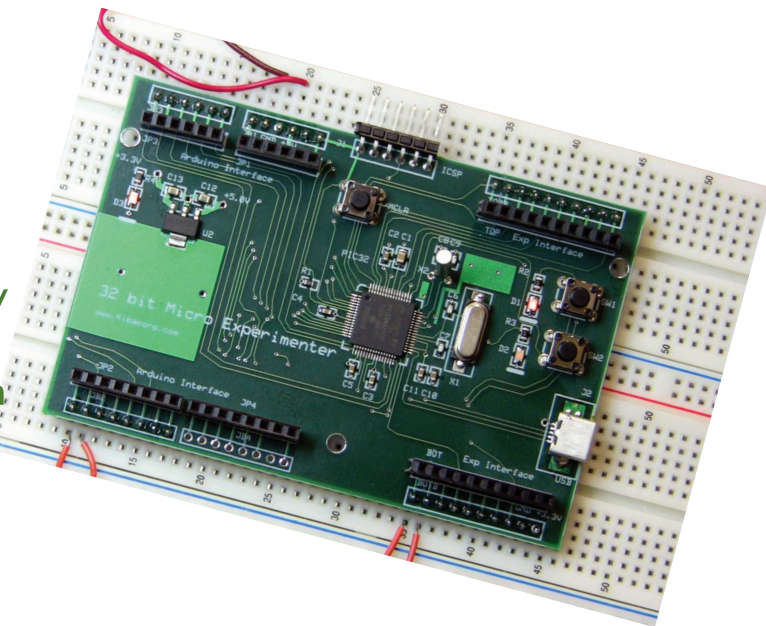


FIGURE 1. The 32-Bit Experimenter.

The Experimenter uses the Microchip 32-bit family of microcontrollers, leveraging what we've learned so far with the 16-bit Experimenter to make the transition to 32-bit easier. This makes sense because of the significant overlap between Microchip's 32-bit family and their 16-bit family. In fact, the PIC32 — Microchip's new 32-bit offering — supports all the Experimenter's 16-bit PIC24F peripheral operations, as well as a new set of atomic bit operations (more on those in later articles). The 32-bit development tool suite like the MPLAB IDE, PICKIT3, and Microchip C compiler family are similar to those used with the 16-bit set. In addition, peripheral programming has been simplified with a new Microchip C 32-bit program peripheral library set. Again, as with the 16-bit Experimenter, the 32-bit Experimenter requires some familiarity with C language at a high level.

With the Experimenter, we will experience a whole new level of applications. Look for embedded web control, use of Real Time Operating Systems (RTOS), USB, speech playback, high speed (100 MHz) Ethernet, and high resolution graphics — all of which we have come to expect in today's top-end multi-media consumer products. We will explore these together through a series of articles using the 32-bit Micro Experimenter.

The PIC32 Microcontroller — an Overview

Microchip's 32-bit microcontroller — the PIC32 — is the top performer in their product family, offering significant enhancements in speed, memory capability, and performance over all other members. If you require high-end performance for your microcontroller application, then the PIC32 is the processor for you. Let's do some comparisons. Let's compare the PIC32MX695F512H microcontroller (PIC32 bit processor used with the 32-bit Micro Experimenter) to the PIC24FJ64GA002 (the 16-bit microcontroller used on the 16-bit Micro Experimenter), then to the PIC16F887 (common eight-bit microcontroller).

In **Table 1**, a MIPS (Millions of Instructions per second) metric is used to capture execution performance. As shown, the PIC32 runs 5X faster than the PIC24F and 16X faster than the PIC16. The PIC32 also executes instructions with much larger data words — 32 bits versus 16 and eight bits. Finally the PIC32 has the largest compliment of Flash and RAM, allowing it to tackle bigger program applications.

The block diagram of the PIC32 in **Figure 2** shows the internals of the chip. The PIC32 (as shown in the **Table**) is a

PIC32	PIC24F	PIC16
32-bit	16-bit	Eight-bit
512K Flash	64K Flash	8K Flash
128K RAM	8K RAM	386 RAM
80 MHz CLOCK	32 MHz	20 MHz
80 MIPS	16 MIPS	5 MIPS
3.3V operation	3.3V operation	5V operation

Table 1.

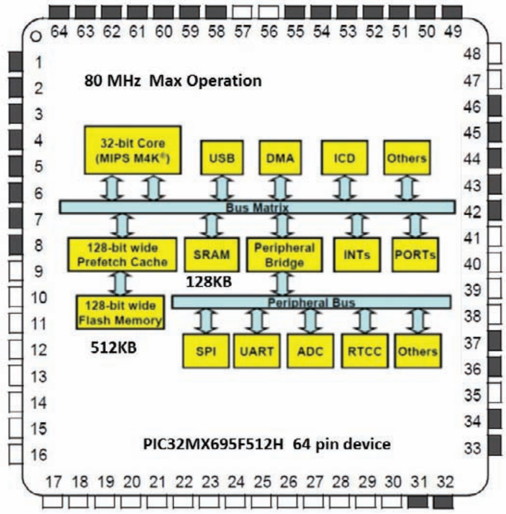


FIGURE 2. PIC32 block diagram.

+3.3V part. However, it can accept +5V logic level inputs on certain pins (see **Figure 2** +5V tolerant pins) without damage. The chip is organized around two internal buses. The top bus is the faster of the two and runs at the system clock CPU rate. It allows simultaneous communications for devices on this bus without any bus contention. Some of the devices here are the 32 Core CPU, the eight channel DMA (Direct Memory Access Controller), and USB. Other components on this bus are Flash, RAM, interrupt controller, all the digital ports, and a peripheral bridge (a connection to all the on-chip peripherals). It is interesting to note that digital ports reside on the high-speed bus. This means they can be toggled (on/off) at the 80 MHz rate —able to generate digital signals of up to 40 MHz if needed. With the use of the DMA, this port (or any other peripheral) can directly access memory without CPU (software) intervention for data transfers. We will show the DMA in action with one of the experiments here.

The other bus is the peripheral bus. This bus does not need to run as fast as the previous bus and can be slowed down to a factor of one to eight (peripheral clock rates are not required to be run as high as 80 MHz). The peripheral bus connects to all the on-chip peripherals. With the PIC32MX695F512H, there are five 16-bit timers, an RTCC (Real Time Clock Calendar), six UARTs (Universal Asynchronous Receiver Transmitter), three SPI (Serial Peripheral Interfaces), four I²Cs (Inter-Integrated Circuits), 16-channel 10-bit ADC (Analog-to–Digital Converter), one PMP (Parallel Master Port), five CCP (Compare/Compare Ports), and two analog comparators. The Experimenter provides us interface access to all these capabilities.

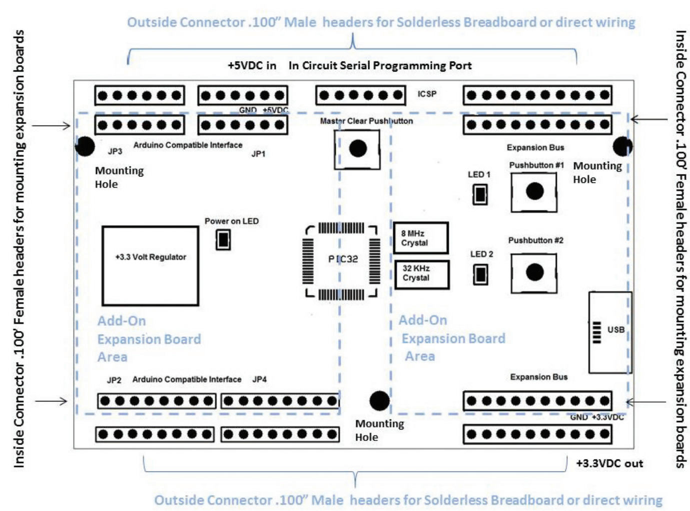


FIGURE 3. EXP32 block diagram.

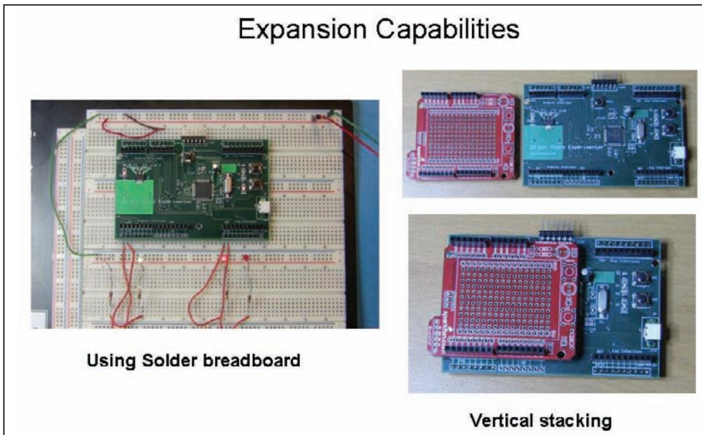


FIGURE 4. Experimenter expansion.

An Overview of 32-Bit Experimenter Hardware

A block diagram of the Experimenter is shown in **Figure 3**; **schematics** are included towards the end of the article. The board has extensive expansion capabilities. This approach allows access to all the PIC32MX695F512H I/O for experiments. The Experimenter inside connectors are .100" female headers. This allows you to mount expansion cards right on top of the Experimenter (vertical expansion). The left side female header top and bottom set has an Arduino expansion footprint that is mechanically and electrically compatible with Arduino expansion cards; the minor exceptions to this interface are shown in red in **Figure 5**. These expansion cards are available from a number of vendors and this feature allows users the opportunity to integrate a number of existing Arduino expansion cards with their Experimenter applications. Keep in mind that new software drivers will have to be rewritten

Power	JP1	ARDUINO	PIC32 EXP
	1	Reset	/MCLR (7)
	2	3.3V	3.3V
	3	5V	5V
	4	gnd	gnd
	5	gnd	gnd
	6	vin	not used

	JP3	ARDUINO	PIC32 EXP
Analog	1	ADC0/PC0	AN0 (16)
	2	ADC1/PC1	AN1(15)
	3	ADC2/PC2	AN2(14)
	4	ADC3/PC3	AN3(13)
	5	ADC4/SDA/PC4	SDA3A(31)
	6	ADC5/SCL/PC5	SCL3A(32)

	JP2	ARDUINO	PIC32 EXP
Digital1	1	RXD/PD0	U1ARX(50)
	2	TXD/PD1	U1ATX(51)
	3	INT0/PD2	INT0 (46)
	4	INT1/PD3	INT1(42)
	5	T0/PD4	NOT0 RE5(1)
	6	T1/PD5	NOT1 RE6(2)
	7	AIN0/PD6	ADN0 C1IN+ (11)
	8	AIN1/PD7	ADN1 C1IN-(12)

	JP4	ARDUINO	PIC32 EXP
Digital2	1	ICP/PB0	IC3(44)
	2	OC1A/PB1	OC5(52)
	3	OC1B/SS/PB2	/SS2A (8)
	4	MOSI/OC2/PB3	SDO2A (6)
	5	MISO/PB4	SDI2A (5)
	6	SCK/PB5	SCK2A (4)
	7	GND	gnd
	8	AREF	NAREF AN8 (21)

Red –not totally compatible

FIGURE 5. Experimenter 48-pin expansion interface.

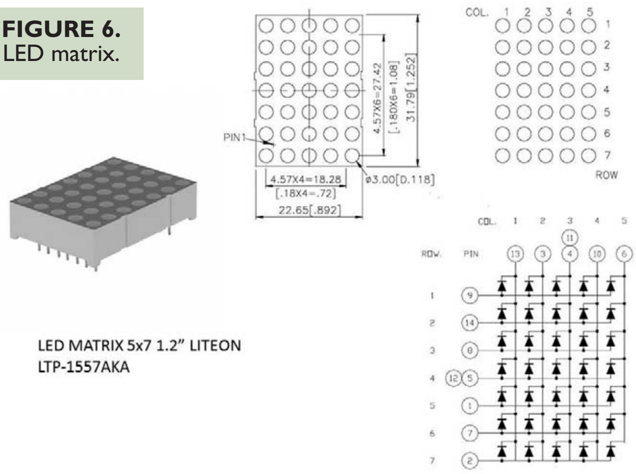


FIGURE 6. LED matrix.

in C to accommodate any of these boards. The Experimenter also uses an additional set of female connectors (top/bottom) on the right side to accommodate non-Arduino expansion boards. For horizontal expansion (typical of solderless breadboarding), the outside connector row sets support .100" male headers. These are used to mount the Experimenter to a large solderless breadboard (3,260 contacts) to accommodate direct wiring prototyping. Finally, the board has three mounting holes that provide mechanical support for vertical expansion or mounting the entire Experimenter to a chassis.

The Experimenter requires a +5 VDC input (500 ma max current) and does onboard regulation of this +5 VDC to generate the necessary +3.3 VDC for the PIC32. A power-up LED signifies that +3.3 VDC is up and running. The +3.3 VDC is also made available for offboard use.

The Experimenter board is programmed and debugged using a standard six-pin ICSP (In Circuit Serial Programming) interface. This interface directly accepts a PICKIT3 programmer/debugger or any of the other programmers/debuggers (with the exception of the PICKIT2). An 8 MHz crystal serves as a CPU clock source and is electronically multiplied inside the chip for 80 MHz operations and for USB clock requirements. The Experimenter also has a fully USB 2.0 compliant interface. USB applications will be covered in detail in subsequent articles. An optional 32 kHz crystal can be added to serve as a precision clock source for the PIC32 Real Time Clock Calendar (RTCC) peripheral for accurate data/time operations.

There is a minimal user interface for manual reset, two software controlled LEDs, and readable pushbutton switches to support debugging and experiments.

Setting Up the Tool Suite

This couldn't be any easier. Go to the Microchip website and download their latest version of MPLAB and the free evaluation copy of the PIC32 C complier. All supplied demos can be easily built and compiled. The only choices you have are the method of programming and debugger hardware. It comes down to the following choices: PICKIT3, MPLAB ICD3, or REALICE. All choices are viable with PICKIT3 being the cheapest. The Experimenter comes pre-configured with an LED blink program that alternately turns off/on each of the two onboard LEDs. This should run "right out of the box" once you apply +5 VDC and ground to JP1 or JB1 connectors. Demo source code — in the form of Microchip projects (.MCP files) — is available on the CD-ROM supplied with the kit or is downloadable from the *Nuts & Volts* website. The demos allow you to exercise your tool suite to build, compile, and download working code into your Experimenter.

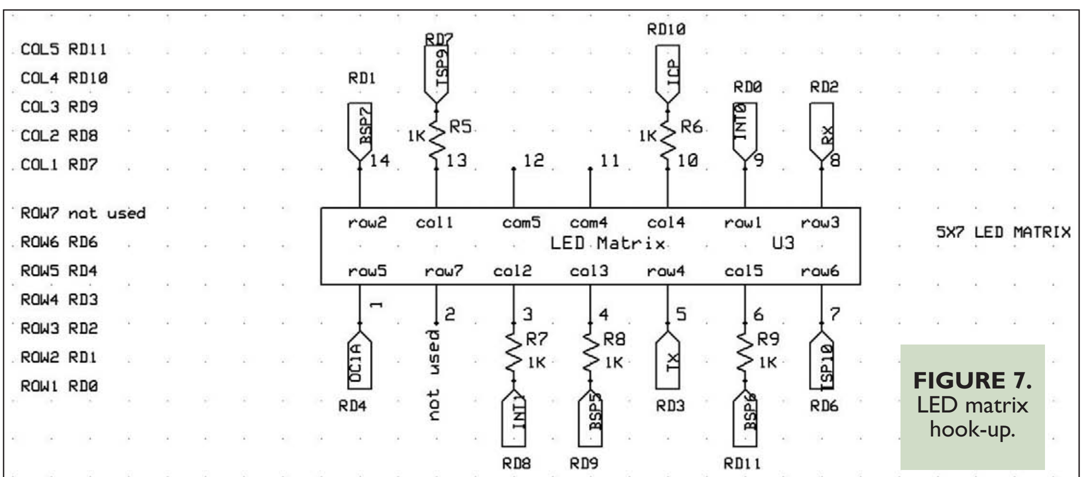


FIGURE 7. LED matrix hook-up.

Hello Word Demos

If you have never heard of C language, you might have heard of the famous "Hello World!" programming example. This is a single line program executed by beginner programmers to display "Hello World!" on a computer screen. So, let's be realistic. We are programming a microcontroller that does not have a computer screen associated with it, so we are limited initially with the Experimenter digital I/O. Fortunately, some of the I/O is connected to its onboard LEDs. In other parts of this series, we will show the use of USB to write to the computer screen, but for now we will use LEDs. To make our "Hello World" meaningful, we will start with the onboard LEDs and then advance to a 5x7 LED matrix for more exciting light shows that demonstrate the use of the RTOS and the PIC32 DMA controller. Here's the run-down:

```
#include <plib.h>
// Configuration Bit settings
// SYSCLK = 80 MHz (8MHz Crystal/ FPLLIDIV * FPLLMUL / FPLLODIV)
// PBCLK = 40 MHz
// Primary Osc w/PLL (XT+,HS+,EC+PLL)
// WDT OFF
// Other options are don't care
#pragma config FNOSC = PRIPLL, POSCMOD = HS, FPLLIDIV = DIV_2, FPLLMUL = MUL_20, FPBDIV = DIV_2, FPLLODIV = DIV_1
#pragma config FWDTEN = OFF
#define SYS_FREQ    80000000        // frequency we're running at

int main(void)
{   int i;
    //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    // Configure the device for maximum performance but do not change the PBDIV
    // Given the options, this function will change the flash wait states, RAM
    // wait state and enable prefetch cache but will not change the PBDIV.
    // The PBDIV value is already set via the pragma FPBDIV option above..
    SYSTEMConfig(SYS_FREQ, SYS_CFG_WAIT_STATES | SYS_CFG_PCACHE);

    // L2 RB11 an output
    // L1 RB12 an output-- Turn them off before changing
    mPORTBClearBits(BIT_12 | BIT_11 );
    mPORTBSetBits(BIT_11 );
    mPORTBSetPinsDigitalOut( BIT_12 | BIT_11 );

    // Now blink all LEDs ON/OFF forever.
    while(1)
    {
        mPORTBToggleBits(BIT_12 | BIT_11  );

        // Insert some delay
        i = 1024*1024;
        while(i--);
    }
}
```

PIC32 and Peripheral Library
Set Fuse Configurations
Library function to configure system for max performance at 80 MHZ
Configure Digital I/O connected to LEDs
Toggle LEDs
Loop
Software Delay

FIGURE 8. Blinky code.

- Demo 1: Blinky LEDs — alternate blinking onboard LEDS (BLINKY.MCP source).
- Demo 2: Turn on the LED with a pushbutton (PUSHBTN.MCP source).
- Demo 3: RTOS individual LED control (RTOS.MCP source).
- Demo 4: DMA transfer to LED (DMA.MCP source).

The particular 5x7 matrix for Demos 3 and 4 is shown in **Figure 6**, along with the hook-up diagram in **Figure 7**. Let's start working through the different experiments.

Demo 1 "Hello World" — Blinky LEDs

The first demo is found in the Blinky folder, so open that folder and double-click on BLINKY.MCP. This should invoke MPLAB and bring up the Blinky project. Select your programmer/debugger, compile the project, and download the code to the Experimenter with your programmer/debugger hooked to ICSP. You should see the two LEDs on the Experimenter blink alternately.

Let's examine the code. All these programs use **#include <plib.h>** to reference the PIC32 library and part. We then set the fuses for 80 MHz operation and the peripheral bus to 40 MHz. Then, we invoke a library function "**SystemConfig()**"to optimize PIC32 operation. This function sets pre-fetch cache, RAM, and Flash wait states for the 80 MHz clock. Finally, we configure the digital I/O for LEDs and enter a continuous loop using a toggle function and a software delay for blink.

Demo 2 "Hello World" — Pushbutton LED

This demo is similar in structure to Demo 1, but responds to either of the two Experimenter pushbuttons being depressed by lighting the corresponding LED associated with the button. This code is shown in **Figure 9**. The project is located in the PUSHBUTTON folder.

Demo 3 "Hello World" — Using an RTOS

An RTOS for microcontrollers is similar to operating

```
#include <plib.h>
#pragma config FNOSC = PRIPLL, POSCMOD = HS, FPLLIDIV = DIV_2, FPLLMUL = MUL_20, FPBDIV = DIV_2, FPLLODIV = DIV_1
#pragma config FWDTEN = OFF
#define SYS_FREQ    80000000        // frequency we're running at

int main(void)
{
    //~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    // Configure the device for maximum performance but do not change the PBDIV
    // Given the options, this function will change the flash wait states, RAM
    // wait state and enable prefetch cache but will not change the PBDIV.
    // The PBDIV value is already set via the pragma FPBDIV option above..
    SYSTEMConfig(SYS_FREQ, SYS_CFG_WAIT_STATES | SYS_CFG_PCACHE);
//setup L1 and L2
    mPORTBClearBits(  BIT_12 | BIT_11 );
    mPORTBSetPinsDigitalOut( BIT_12 | BIT_11 );
//setup S1 RB15/CN12
    mPORTBSetPinsDigitalIn( BIT_15 );
//setup S2 RD5/CN14
mPORTDSetPinsDigitalIn( BIT_5 );
    /* enable pullups on change notice pins 12,14 */
ConfigCNPullups(CN14_PULLUP_ENABLE | CN12_PULLUP_ENABLE);
    while(1)
    {   if(PORTDbits.RD5 == 0)
        mPORTBSetBits( BIT_11)  ;
        else
        mPORTBClearBits( BIT_11);

            if(PORTBbits.RB15 == 0)
        mPORTBSetBits( BIT_12)  ;
        else
        mPORTBClearBits( BIT_12);
    }
}
```

PIC32 and Peripheral Library
Set Fuse Configurations
Library function to configure system for max performance at 80 MHZ
Configure Digital I/O connected to LEDs and connect to switches Set weak pull up resistors to switches
Check Switch1 and turn on LED1
Loop
Check Switch2 and turn on LED2

FIGURE 9. Pushbutton code.

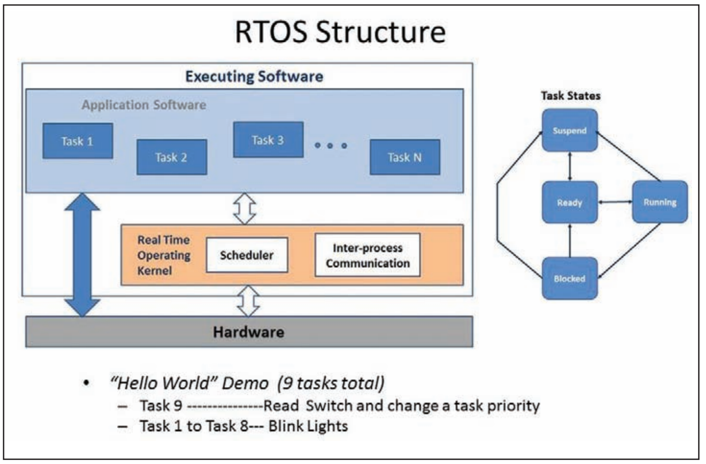


FIGURE 10. RTOS structure overview.

systems like Windows and Linux for PCs and workstations, and these are now making an impact in high-performance microcontrollers like the PIC32. In fact, with the computational power and memory of the PIC32, an RTOS is needed to efficiently process lots of simultaneous complex multi-task software operations at the same time. The best way to visualize this is to appreciate the types of applications that these advanced microcontrollers are handling today. In this demo, you will be introduced to a free open source RTOS for the PIC32 developed by Richard Barry (see **www.freertos.org**).

FreeRTOS allows PIC32 applications to be organized as a collection of independent tasks operating under control of a real time scheduler (see **Figure 10**). The scheduler decides which task should be executing by examining the priority assigned to each task by the application designer. Tasks can move from running to block or to ready or suspended, depending on the priority and how you design them. In this demo, we will cover task creation, scheduling, removal, and reinstatement, as well as interrupt handling. We will use FreeRTOS to perform our "Hello World" function. It's a modest start but highlights the powerful capabilities of organizing your code around an RTOS. To make things interesting, we will create the ability to simultaneously handle independent LED blinking tasks — each task assigned to blink an individual LED. This demo requires use of the LED matrix and the hook-up diagram mentioned earlier. As you push and release SW1, an individual LED blinking task will be dynamically eliminated until the max of eight tasks is reached. At this point, as you continue to depress SW1; tasks that were previously eliminated are restored in reverse order. The main code is shown in **Figure 11**. The functions used are described in the on-line documentation associated with FreeRTOS. Here's a quick overview:

- **vSetupEnvironment()** — Encapsulates the code to set up the hardware (in this case, eight LEDs and a switch).
- **xTaskCreate(vTask1,"Task 1",240,(void*)image,1,&xTask1Handle)** — Creates a "task 1" and passes it an image (digital port value of the row/column for a specific LED in the matrix). This task can be referenced later by its handle. The task is written as an LED blink function.
- **vSemaphoreCreateBinary (xBinarySemaphore)** — Creates a semaphore or binary flag/control that will be used uniquely by the switch interrupt service to invoke its task handler.
- **xTaskCreate(vHandlerTask, "Handler", 240, NULL, 3, NULL)** — Creates a task to handle the switch once an interrupt occurs. The interrupt invokes this task using the above semaphore; the handler adds and removes tasks by their handles.
- **vTaskStartScheduler()** — Starts the RTOS scheduler so that the tasks created so far start executing.

It is interesting to watch the LED activity as the FreeRTOS scheduler spreads and de-spreads the PIC32 processing power across the blinking tasks. This demo is included in the folder named RTOS example. Open this folder and navigate to examples, and then open RTOSEXAMPLE.MCP. This demo is also available for download from the *NV* website.

```
int main( void )
{
    /* Configure both the hardware and the debug interface. */
    vSetupEnvironment();
    int image = LED11; //image is col row setting for col 1 row 1 LED
    xTaskCreate( vTask1,"Task 1",240,(void*)image,1,&xTask1Handle );
    image = LED12;
    xTaskCreate( vTask2, "Task 2", 240,(void*)image, 1, &xTask2Handle );
    image = LED13;
    xTaskCreate( vTask3, "Task 3", 240, (void*)image, 1, &xTask3Handle );
    image = LED14;
    xTaskCreate( vTask4, "Task 4", 240, (void*)image, 1, &xTask4Handle );
    image = LED15;
    xTaskCreate( vTask5, "Task 5", 240, (void*)image, 1, &xTask5Handle );
    image = LED16;
    xTaskCreate( vTask7, "Task 7", 240, (void*)image, 1, &xTask7Handle );
    image = LED17;
    xTaskCreate( vTask8, "Task 8", 240, (void*)image, 1, &xTask8Handle );
    /* Before a semaphore is used it must be explicitly created.  In this example
    a binary semaphore is created. */
    vSemaphoreCreateBinary( xBinarySemaphore );
    /* Check the semaphore was created successfully. */
    if( xBinarySemaphore != NULL )
    {   /* Create the 'handler' task.  This is the task that will be synchronized
        with the interrupt.  The handler task is created with a high priority to
        ensure it runs immediately after the interrupt exits.  In this case a
        priority of 3 is chosen. */
        xTaskCreate( vHandlerTask, "Handler", 240, NULL, 3, NULL );
        /* Start the scheduler so the created tasks start executing. */
        vTaskStartScheduler();
    }
         /* If all is well we will never reach here as the scheduler will now be
    running the tasks.  If we do reach here then it is likely that there was
    insufficient heap memory available for a resource to be created. */
    for( ;; );
    return 0;
}
```

FIGURE 11. RTOS 'Hello World' code.

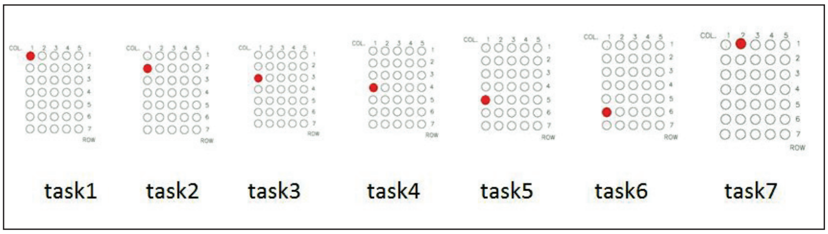


FIGURE 12. RTOS 'Hello World' (seven tasks shown).

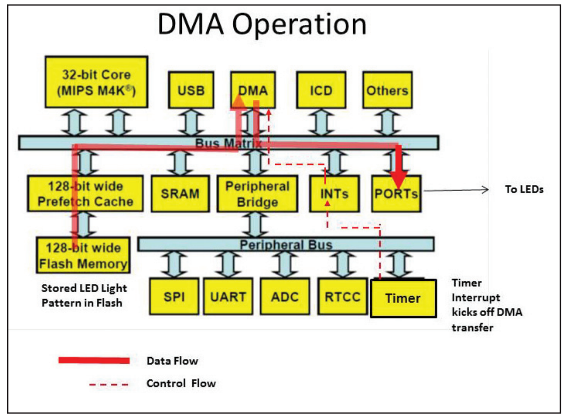


FIGURE 13. DMA demo.

Demo 4 "Hello World" — Using PIC32 DMA

We'll now demonstrate a different "Hello World" using the DMA controller to refresh the LED matrix. Here, we are servicing all 35 LEDs where each LED is individually controlled using the DMA in conjunction with the digital I/O and timer. The I/O port is configured to drive all rows and columns of the LED matrix for 35 individual LEDs. These individual LED patterns are stored as a 1500 word C array (LED_PATTERN) in Flash. DMA allows us to bypass the CPU and transfer directly to the I/O port. The DMA transfers occur as part of a timer 23 (32-bit timer) peripheral interrupt (which occurs every 10 milliseconds). DMA updates the LEDs with the specific array pattern synchronized to this interrupt. This demo is DMA.MCP and is also available for download. The demo creates a dynamic light show with individual control of 35 LEDS to display random patterns between a distinct "d," "M," "A" display on the LED matrix (**Figure 15**). The main code is shown in **Figure 14** and draws heavily on the DMA peripheral library. Note the final loop. All of the DMA activities occur while the CPU is simply executing the original blinky "Hello World" demo. This is truly a powerful demonstration of the PIC32 DMA.

What's Next?

The Experimenter represents a new, affordable, and exciting way of getting involved with 32-bit microcontrollers. The PIC32 is currently recognized as one of the best in its class, so what's a better way to get started than with 32-bit microcontrollers? It leverages off of your 16-bit Experimenter experience. A lot of what was learned and covered during the 16-bit series is still pertinent here.

There will be a lot of ground to cover to help realize efficiency with this new technology. Given the expandability of the Experimenter, there are many ways to realize this potential. In upcoming articles, we hope to pave the way with directions to USB, Ethernet, speech, and high resolution graphics to name a few. **NV**

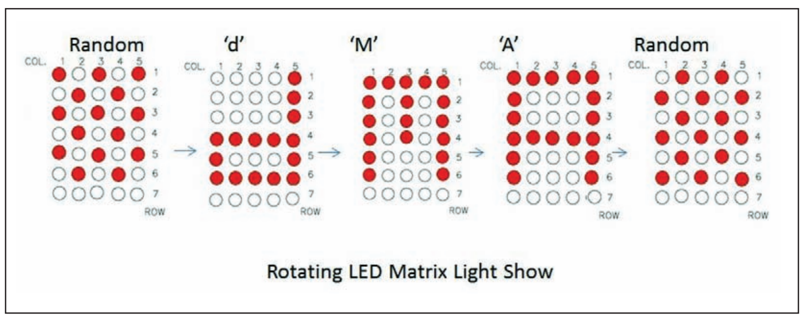


FIGURE 15. DMA 'Hello World' demo.

FIGURE 14. DMA 'Hello World' code.

```
int main(void)
{
    int dmaChn=0;        // the DMA channel to use
    //set up outptus for on-board blinking LEDs
    mPORTBClearBits(BIT_12 | BIT_11 );
    mPORTBSetBits(BIT_11 );
    mPORTBSetPinsDigitalOut( BIT_12 | BIT_11 );

    //set the digital outputs for the matrix
    mPORTDSetBits(BIT_11 | BIT_10 | BIT_9 | BIT_8 |BIT_7  ); // turn off columns
    mPORTDClearBits( BIT_6 |BIT_5 | BIT_4 | BIT_3 | BIT_2 |BIT_1 | BIT_0 ); //clear rows
    mPORTDSetPinsDigitalOut(BIT_11 | BIT_10 | BIT_9 | BIT_8 |BIT_7 | BIT_6 |BIT_5 | BIT_4 | BIT_3 | BIT_2 |BIT_1 | BIT_0 );

    // Open the desired DMA channel.
    // We enable the AUTO option, we'll keep repeating the sam transfer over and over.
    DmaChnOpen(dmaChn, 0, DMA_OPEN_AUTO);

    // set the transfer parameters: source & destination address, source & destination size, number of bytes per event
    DmaChnSetTxfer(dmaChn, LED_pattern, (void*)&LATD, sizeof(LED_pattern), 2, 2); //desination =2 and tranfer =2
    // set the transfer event control: what event is to start the DMA transfer
    DmaChnSetEventControl(dmaChn, DMA_EV_START_IRQ(_TIMER_3_IRQ));
    // once we configured the DMA channel we can enable it
    // now it's ready and waiting for an event to occur...
    DmaChnEnable(dmaChn);
    // now use the 32 bit timer to generate an interrupt at the desired LED_BLINK_RATE
    {
        int pbFreq=SYS_FREQ/(1<<mOSCGetPBDIV());    // get the PB frequency the timer is running at
        // use 1:1 prescaler for max resolution, the PB clock
        OpenTimer23(T2_ON | T2_SOURCE_INT | T2_PS_1_1, (pbFreq/1000/4)*LED_BLINK_RATE);
    }
    while(1)
    {
        // do some other useful work
            mPORTBToggleBits(BIT_12 | BIT_11  );
            delay();
    }
```

Initialize on board blinking lights

Initialize LED Matrix

Open DMA channel 0

Set 1 word transfer between FLASH array and PORTD

Start 32 bit timer23

Default non-DMA blink loop

■ BY LOUIS E. FRENZEL W5LEF

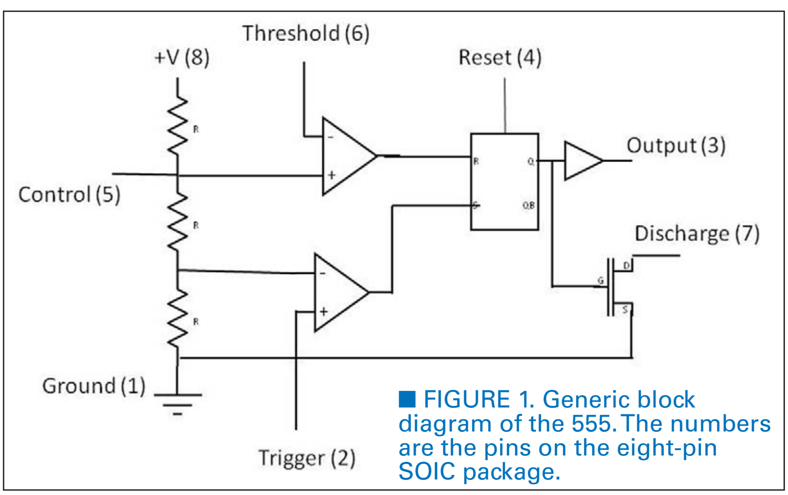
555 TIMER IC REINVENTED — NEW VERSIONS OF THIS LEGACY CHIP EXTEND ITS LIFE

Who hasn't used a 555 timer IC? If you are an engineer, technician, teacher, hobbyist, or an electronic whatever, chances are you have encountered the ubiquitous 555. This "ancient" chip was introduced by Signetics (then Philips, then NXP) in 1971. It was an instant hit because of its incredible versatility. That chip spawned thousands of applications circuits from simple audio oscillators to sophisticated timers, and dozens of other unique circuits. Literally, billions have been sold. Despite the widespread use of cheap single-chip microcontrollers, the 555 timer still seems to find a place in school labs and even some new products.

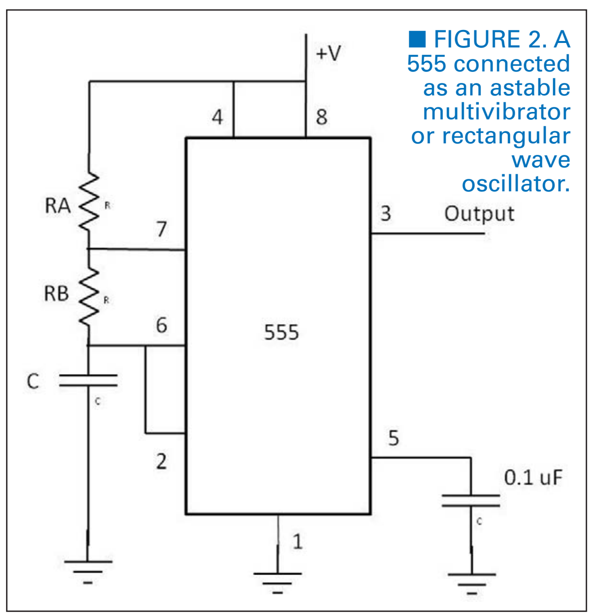
While the legacy 555 continues its popularity, that basic design just may garner some renewed interest thanks to two new and improved versions of this chip recently by Advanced Linear Devices and Semtech. Here is a look at this incredible chip and the new models that may further its longevity.

555 BASICS

The architecture of the 555 is simplicity itself (see **Figure 1**). It consists of a simple set-reset flip-flop driven by two comparators. The comparators get their inputs from an internal three-resistor voltage divider and some outside signals. The voltage divider sets the threshold and trigger levels at two thirds and one third, respectively, of the +V supply voltage. When the trigger input is less than the trigger level, the output is high. When the threshold input is higher than the threshold simultaneously with the trigger input being higher than the trigger level, the flip-flop is reset and the output goes low. The trigger and threshold inputs usually come from an external capacitor. The discharge output is used to switch the capacitor. A reset input overrides any other input condition when it goes



■ FIGURE 1. Generic block diagram of the 555. The numbers are the pins on the eight-pin SOIC package.

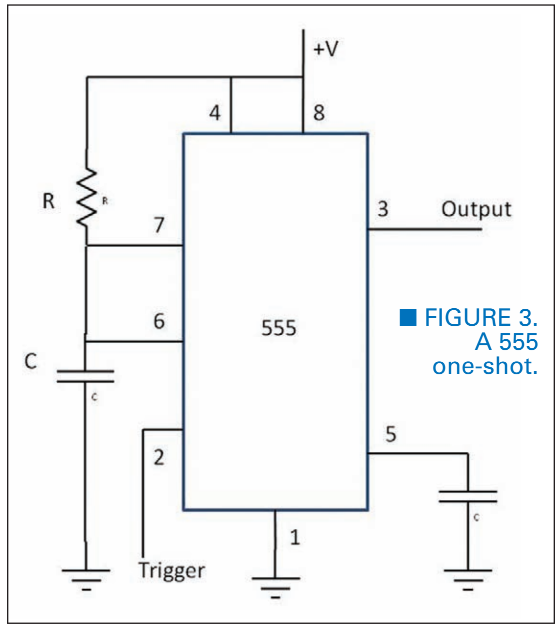


■ FIGURE 2. A 555 connected as an astable multivibrator or rectangular wave oscillator.

low. There are two classical circuits used with the 555. The first in **Figure 2** is an astable multivibrator or free-running oscillator. External capacitor C charges through R_A and R_B and discharges through R_B. The charging and discharging of the capacitor triggers the comparators alternately setting and resetting the flip-flop; this produces a rectangular output waveform. The frequency (f) is given by:

$$f = 1.46/(R_A + 2R_B)C$$

■ FIGURE 5. Semtech's SX8122 555-like IC.



■ FIGURE 3. A 555 one-shot.

The duty cycle (DC) is given by:

$$DC = R_B / (R_A + 2R_B)$$

With the older 555s, the upper frequency limit was a few hundred kilohertz (kHz) at best. The duty cycle was not 50% as is usually desirable, but more like 45%. Yet many circuits used this configuration. With large external resistors and an electrolytic capacitor, the output frequency could be as low as a few Hz — great for flashing LEDs. The other popular circuit is a one-shot or monostable as shown in **Figure 3**. A single input trigger voltage initiates a single output pulse whose duration (t) is given by:

$$T = 1.1RC$$

This circuit was good for generating a delay or a sequence of timed pulses. The 555 can also be used in a variety of circuits; way too many to list here. Some examples are a pulse width modulator (PWM), variable frequency oscillator (VCO), and a DC-DC converter. Just search '555 timer' with your browser to find a jillion or more application circuits. *Nuts & Volts* has published thousands of 555 circuits over the years, as well.

ADVANCED LINEAR DEVICES' 555

Advance Linear Devices recently announced their improved version of the 555 called the ALD7555 and its companion dual timer version the ALD7556. It is made from CMOS, unlike the original bipolar versions of the 555 (see **Figure 4**). It features 200K ohm voltage divider resistors instead of the original 5K parts. This gives the device lower power consumption and higher input impedances. The device also includes an internal MOSFET driver transistor (see **Figure 1** again) that was usually an external transistor in some 555 designs.

The ALD7555/7556 offers much lower power consumption and high input impedance permitting battery operation. This also allows smaller external timing capacitors and larger external resistors that greatly simplify and decrease the cost of a design. It also means a higher frequency of operation; in this case, ALD specifies up to 2.5 MHz. The temperature stability is improved. With less internal leakage, these devices can produce more accurate frequencies or delays, as well as much longer pulses. A 50% duty cycle astable mode is also possible.

The ALD7555/7556 operates from a supply voltage of two to 10 volts. Its output sinking current is 80 mA at five volts making it capable of driving an LED, relay, or small speaker directly. The pin-out is exactly the same as the original 555/556 ICs. Both eight- and 14-pin SOIC

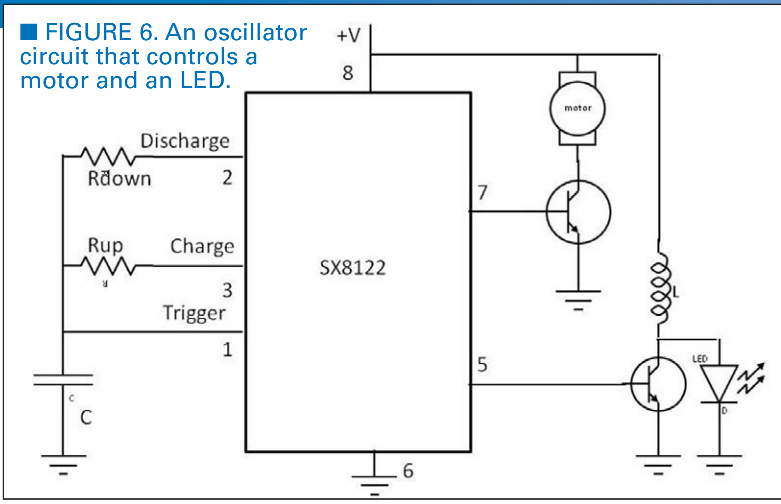
■ FIGURE 4. Advanced Linear Devices' ALD7555/7556 ICs.

packages are available.

SEMTECH'S 555

The new Semtech version of the 555 is called the SX8122 (**Figure 5**). It uses the same basic architecture with the two comparators toggling a flip-flop to create an oscillator or one-shot. It also offers some other really neat features and capabilities. First, it is designed to work with a supply voltage in the 0.9 to 2.0 volt range. That means it will work with AA or AAA alkaline cells, or even NiMH or NiCd cells. Plus, it functions all the way down to 0.9 volts. Second, it offers some low voltage features that lets it control a DC motor or some other continuous low voltage element. Another unique output is one that generates a 41 kHz burst pulse train to drive a high brightness LED. This combination of low voltage, low power, and the unique outputs makes it a great choice when making consumer products like electric toothbrushes, buzzers, toys, and LED pointers. The SX8122 also has a voltage monitor for detecting when the supply voltage is above or below 1.41 volts — the threshold of an NiMH battery. This output can control a minimal USB charger. **Figure 6** shows one application. Note that the pin-out is not the same as the original 555. The single capacitor and the two resistors set the oscillation frequency. One resistor (Rup) controls the charge and the other (Rdown) the discharge of the capacitor. The threshold voltages on the trigger pin are set to the 1/3 and 2/3 of the supply voltage as in the original 555. Note the motor and LED output pins which control external transistors that switch the motor and LED. Long live the 555! With these two new variations, some interesting new circuits and products can be created. If you have never used a 555, try one of these new devices. You'll get hooked on the 555 like the rest of us have been for years. **NV**

■ FIGURE 6. An oscillator circuit that controls a motor and an LED.



ELECTRONET

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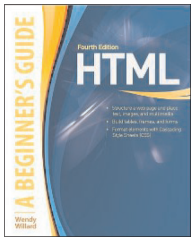
ELECTRONICS

NEW!

HTML: A Beginner's Guide
by Wendy Willard

Essential HTML Skills Made Easy!



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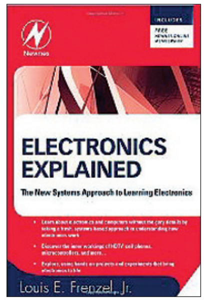
Electronics Explained
by Louis Frenzel

The New Systems Approach to Learning Electronics



Don't spend time reading about theory, components, and old ham radios - that's history! Industry veteran, Louis Frenzel, gives you the real scoop on electronic product fundamentals as they are today. Rather than tearing electronics apart and looking at every little piece, the author takes a systems-level view. For example, you will not learn how to make a circuit but how a signal flows from one integrated circuit (IC) to the next, and so on to the ultimate goal.

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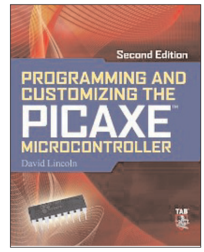
Programming and Customizing the PICAXE Microcontroller 2/E
by David Lincoln

UNLEASH THE POWER OF THE PICAXE!

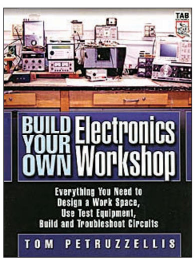


The PICAXE is a powerful and easy-to-use processor, capable of highly sophisticated projects, without the complexities and high costs of alternative chips. Beginners can produce tangible results within minutes, and experienced users can achieve truly professional results. This Second Edition has been fully updated for the latest hardware and software upgrades, and shows you step-by-step how to take full advantage of all the capabilities of the PICAXE and build your own control projects.

$49.95*

Build Your Own Electronics Workshop
by Thomas Petruzzellis

BUILD YOUR OWN DREAM ELECTRONICS LAB!



This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components to putting the shop into action -- building, testing, and troubleshooting systems. This great book has it all! And the best part is, it shows you how to build many pieces of equipment yourself and save money, big time!

Reg Price $29.95
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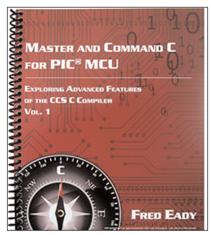
Master and Command C for PIC MCUs
by Fred Eady

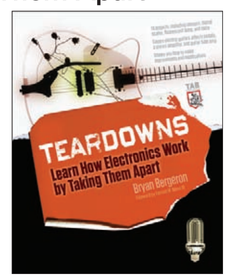


Master and Command C for PIC MCU, Volume 1 aims to help readers get the most out of the Custom Computer Services (CCS) C compiler for PIC microcontrollers. The author describes some basic compiler operations that will help programmers, particularly those new to the craft create solid code that lends 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.

$14.95

TEARDOWNS
by Bryan Bergeron

Learn How Electronics Work by Taking Them Apart



Amp up your knowledge of electronics by deconstructing common devices and analyzing the revealed components and circuitry. *Teardowns: Learn How Electronics Work by Taking Them Apart* contains 14 projects that expose the inner workings of household appliances, workbench measuring instruments, and musical equipment. Discover how resistors, capacitors, sensors, transducers, and transistors function in real circuitry.

Reg $24.95 **Sale Price $21.95**

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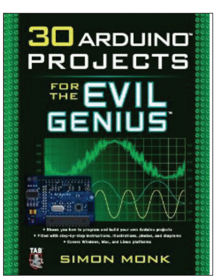
30 Arduino Projects for the Evil Genius
by Simon Monk

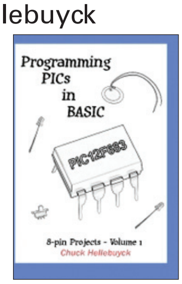
30 Ways to Have Some Computer-Controlled Evil Fun!



Using easy-to-find components and equipment, this do-it-yourself book explains how to attach an Arduino board to your computer, program it, and connect electronics to it to create fiendishly fun projects. The only limit is your imagination!

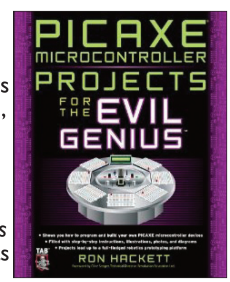
$24.95

Programming PICs in Basic
by Chuck Hellebuyck



If you wanted to learn how to program microcontrollers, then you've found the right book. Microchip PIC microcontrollers are being designed into electronics throughout the world and none is more popular than the eight-pin version. Now the home hobbyist can create projects with these little microcontrollers using a low-cost development tool called the CHIPAXE system and the BASIC software language. Chuck Hellebuyck introduces how to use this development setup to build useful projects with an eight-pin PIC12F683 microcontroller. **$14.95**

PICAXE Microcontroller Projects for the Evil Genius
by Ron Hackett



This wickedly inventive guide shows you how to program, build, and debug a variety of PICAXE microcontroller projects. *PICAXE Microcontroller Projects for the Evil Genius* gets you started with programming and I/O interfacing right away, and then shows you how to develop a master processor circuit.

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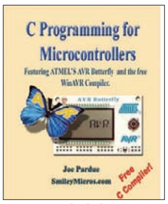
BOOK & KIT COMBOS



From the
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C Programming for
Microcontrollers
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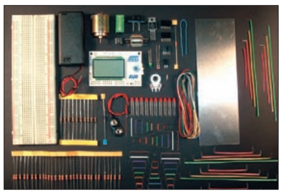

Book **$44.95**

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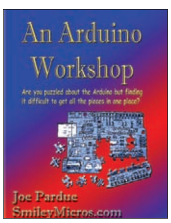
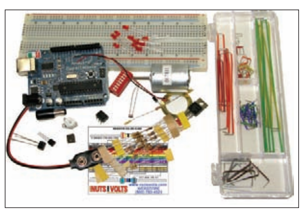
Do you want a low cost way to learn C programming for microcontrollers? This 300 page book and software CD show you how to use ATMEL's AVR Butterfly board and the FREE WinAVR C compiler to make a very inexpensive system for using C to develop microcontroller projects.

Combo Price $99.95 Plus S/H



From the
Smiley Workshop
An Arduino
Workshop
by Joe Pardue

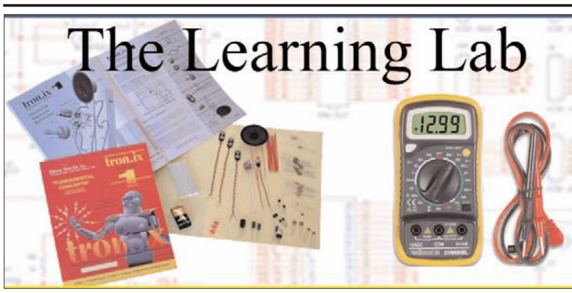


The book *An Arduino Workshop* and the associated hardware projects kit bring all the pieces of the puzzle together in one place. With this, you will learn to: blink eight LEDs (Cylon Eyes); read a pushbutton and 8-bit DIP switch; sense voltage, light, and temperature; make music on a piezo element; sense edges and gray levels; optically isolate voltages; fade an LED with PWM; control motor speed; and more!

An Arduino Workshop Combo

Reg Price $ 124.95 **Subscriber's Price $119.95 Plus S/H**

CD ROM SPECIALS



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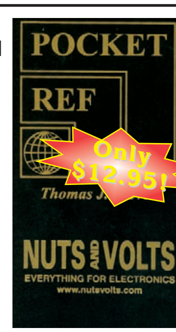

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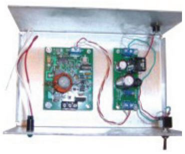
PROJECTS

Mini-Bench Supply Complete Kit



A small power supply with +5V, +12V, and -12V outputs is a handy thing to have around when you're breadboarding circuits with both op-amps and digital ICs.

Kit includes: Enclosure box, accessories, DC-to-DC converter kit, switching regulator kit, and article reprint.
For more information, please see the "feature article section" on the top right side of the *Nuts & Volts* website.

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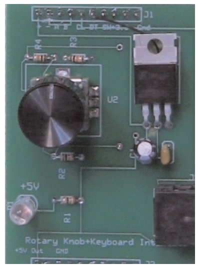
The Mini Kit



The best experiment yet for the 16-Bit Experimenter Board.

Adding this Mini Kit to your Experimenter Board will enhance the Experimenter. The Mini Kit is a user interface with a rotary encoder using the PIC24F timer peripheral set and its interrupt capability.
For more information, see the December 2010 issue
Assembled units also available.

Subscriber's Price **$36.95**
Non-Subscriber's Price **$39.95**

Piezoelectric Film Speaker Kit

As seen in the November issue, here is a great project to amaze your friends and to demonstrate a unique way of producing sound. Kit contains one piece of piezoelectric film, speaker film stand, PCB, components, audio input cable, and construction manual. All you'll need to add is a battery and a sound source.
For more info, please visit our website.

Subscriber's Price **$69.95**
Non-Subscriber's Price **$74.95**

Garage Door Alarm PCB & Chips

As seen in the November 2010 issue.
Is Your Garage Door Open?
This project uses the latest in wireless technology, and is a fun and easy project to build. We provide the difficult parts: the transmitter and receiver PCBs with their matching programmed MCUs. The other components can be fould at your favorite parts house.
Includes an article reprint.

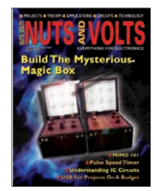
Subscriber's Price **$29.95**
Non-Subscriber's Price **$31.95**

16-Bit Micro Experimenter Board

Ready to move on from 8-bit to 16-bit microcontrollers? Well, you're in luck! In the December 2009 *Nuts & Volts* issue, you're introduced to "the 16-Bit Micro Experimenter." The kit comes with a CD-ROM that contains details on assembly, operation, as well as an assortment of ready-made applications. New applications have been added since inception.

Subscriber's Price **$59.95**
Non-Subscriber's Price **$55.95**

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.
Includes an article reprint.

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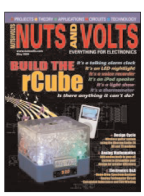
rCube Talking Alarm Clock Kit

As seen on the May 2009 cover



Available in blue, black, red, and green. All components are pre-cut and pre-bent for easier assembly and the microcontrollers are pre-programmed with the software. Kits also include PCB, AC adapter, and instructions on CD-ROM.

Subscriber's Price **$49.95**
Non-Subscriber's Price **$54.00**

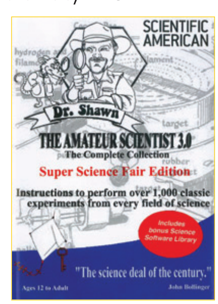
Transistor Clock Kit

If you like electronic puzzles, then this kit is for you! There are no integrated circuits; all functionality is achieved using discrete transistor-diode logic. The PCB is 10"x11" and harbors more than 1,250 components! For more info, see the November 2009 issue.

Reg $225.95
Sale Price $199.95
PCBs can be bought separately.

The Amateur Scientist 3.0 The Complete Collection

by Bright Science, LLC



There are 1,000 projects on this **CD**, not to mention the additional technical info and bonus features. It doesn't matter if you're a complete novice looking to do their first science fair project or a super tech-head gadget freak; there are enough projects on the single CD-ROM to keep you and 50 of your friends busy for a lifetime!

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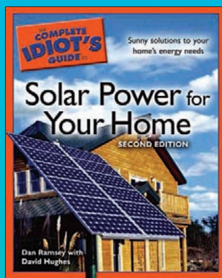
ALTERNATIVE ENERGY SECTION

The Complete Idiot's Guide to Solar Power for Your Home
by Dan Ramsey / David Hughes



The perfect source for solar power — fully illustrated. This book helps readers understand the basics of solar power and other renewable energy sources, explore whether solar power makes sense for them, what their options are, and what's involved with installing various on- and off-grid systems.

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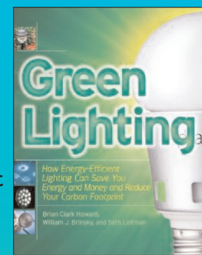
NEW!

Green Lighting
by Brian Clark Howard, Seth Leitman, William Brinsky

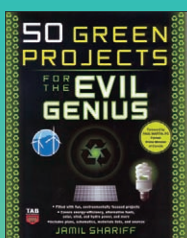
Flip the switch to energy-efficient lighting!



This do-it-yourself guide makes it easy to upgrade residential and commercial lighting to reduce costs and environmental impact while maintaining or even improving the quality of the lighting. Filled with step-by-step instructions and methods for calculating return on investment, plus recommended sources for energy-efficient products.

$24.95

50 Green Projects for the Evil Genius
by Jamil Shariff

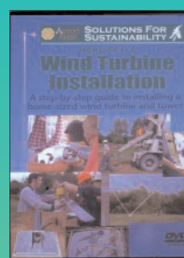


Using easy-to-find parts and tools, this do-it-yourself guide offers a wide variety of environmentally focused projects you can accomplish on your own. Topics covered include transportation, alternative fuels, solar, wind, and hydro power, home insulation, construction, and more. The projects in this unique guide range from easy to more complex and are designed to optimize your time and simplify your life!

$24.95

NEW!

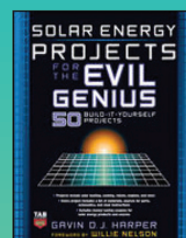
Wind Turbine Installation DVD



Manuals can sometimes be confusing, especially for people who learn by seeing how things work. So, this DVD takes the viewer step-by-step through the entire installation process, from choosing a site, to running wire, assembling the tower, and finally using a winch for the final lift. This is a must-watch for anyone planning on installing a wind turbine who wants to learn the process and the proper techniques for a safe and successful installation.

$19.95*

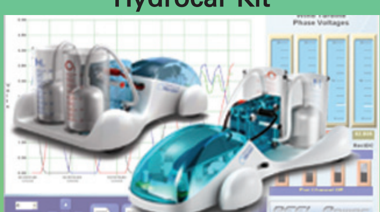
Solar Energy Projects for the Evil Genius
by Gavin D J Harper



Let the sun shine on your evil side — and have a wicked amount of fun on your way to becoming a solar energy master! In *Solar Energy Projects for the Evil Genius*, high-tech guru Gavin Harper gives you everything you need to build more than 30 thrilling solar energy projects. You'll find complete, easy-to-follow plans, with clear diagrams and schematics, so you know exactly what's involved before you begin.

$24.95

Hydrocar Kit



The Hydrocar is used in a couple of great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 10 and 11, he teaches you the operation of the Polymer Electrolyte Membrane "reversible" fuel cell. For kit details and a demo video, please visit our webstore.

Subscriber's Price **$79.95**
Non-Subscriber's Price **$84.95**

Solar Hydrogen Education Kit

The Solar Hydrogen Education Kit includes a solar cell, a PEM reversible fuel cell, oxygen and hydrogen gas containers, and more! The set only needs pure water to create hydrogen and produce electricity. Perfect for science labs, classroom use, or demonstration purposes.

Subscriber's Price **$56.95**
Non-Subscriber's Price **$59.95**

Windpitch Kit

The WindPitch Wind Turbine Kit is a miniature real-working wind turbine and is one of the great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 8 and 9, he teaches you how to produce the most power by evaluating the pitch (setting angle) of the profiled blades. For kit details, please visit our webstore.

Subscriber's Price **$84.95**
Non-Subscriber's Price **$89.95**

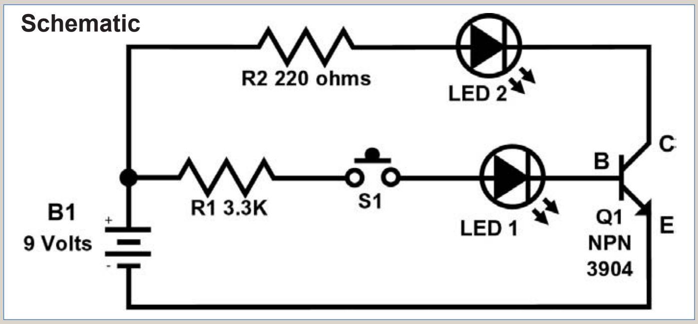
FUNDAMENTALS FOR THE BEGINNER

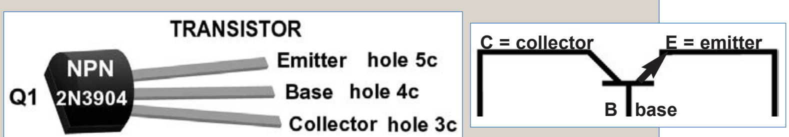
HOW AN NPN TRANSISTOR WORKS

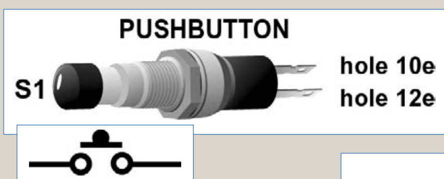
In this experiment, we will build a simple circuit to observe an NPN transistor serving as a current amplifier.

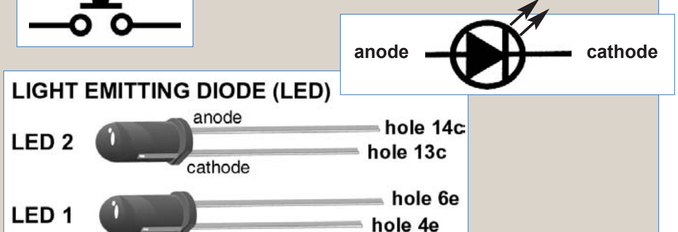
1. Build the Circuit.

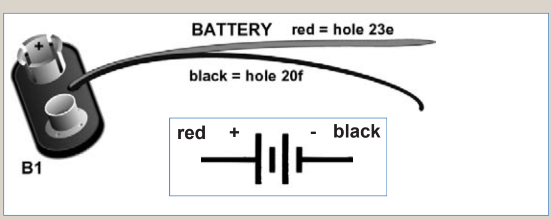
Using the schematic along with the pictorial diagram, place the components on a solderless breadboard as shown. Verify that your wiring is correct.

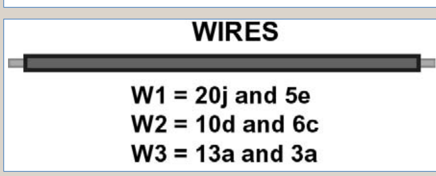










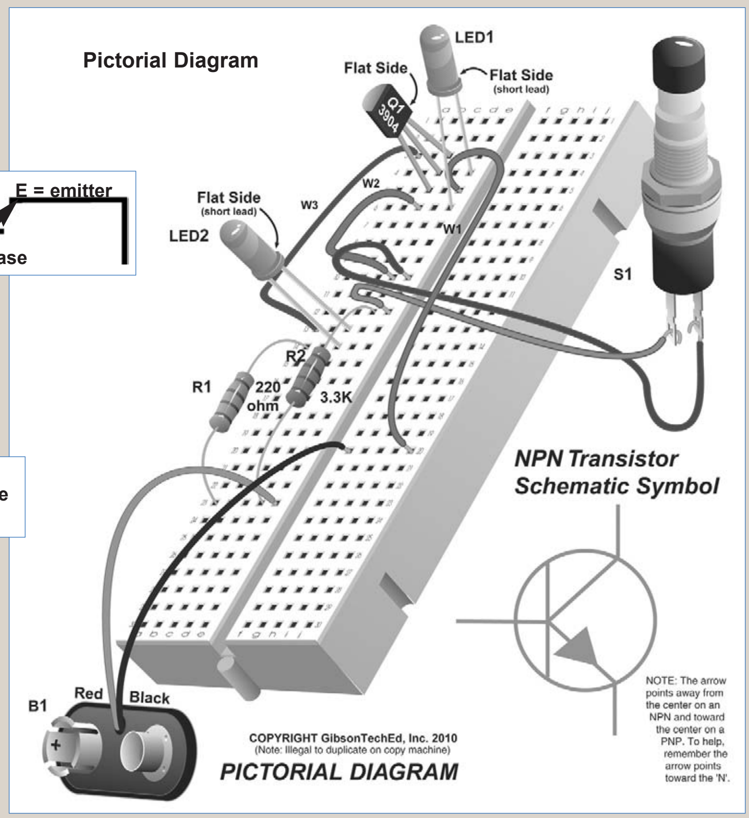


2. Do the Experiment.

Theory: In this circuit, the electrons flow from the negative of the battery through the emitter, the base, LED1, the switch, the 3,300 ohm resistor, then back to the positive of the battery. At the same time, electrons flow through the collector, LED2, and the 220 ohm resistor. Notice that electrons do not flow until the switch is pressed. There must be emitter-base current before any current will flow in the emitter-collector circuit. This act of a smaller current controlling a larger current is referred to as amplification. Within limits, as we increase the current in the emitter-base circuit it will increase the current flowing in the emitter-collector circuit. By adjusting the value of R1, you can use an ammeter to observe the change in currents.

Procedure: Connect a nine-volt battery to the battery snap and press the pushbutton switch to cause current to flow. Both LEDs should light up. When you release the pushbutton switch, both LEDs should turn off.

In doing this experiment, you can see that the NPN transistor is working as a current amplifier, sending more current through LED2 than LED1.



These experiments are provided by GSSTechEd at **www.gssteched.com**
You can order parts for this experiment from their website as follows:

GK01049	220 ohm resistor
GK01077	3.3K ohm resistor
GK06001	Red LED
GK18001	NPN Transistor
GK25006	Pushbutton Switch with wires
GK35002	Battery Snap
GK45011	Solid Hookup Wire

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>>> QUESTIONS

Ground Control Rocketry Interface

We do model rocketry; all the way to high powered and experimental.

I want to build ground equipment to use my laptop to control rocket launches. I would like to use a microcontroller to run one to 20 launch pads using my computer to send a signal to a relay when I am given the "go ahead for launch." I need someone to point me in the right direction for a microcontroller and software. I prefer something USB based.

#2111 **Clifford W. Crawford**
Temple, TX

High Frequency Transmitter Design

Where can I find a very high frequency transmitter circuit, in the 10 GHz range, less than one watt in output (experiment only, non-commercial grade)?

#2112 **Rick Rhinehouse**
New York City, NY

PC Joystick Interfacing

In years past, PC joysticks contained only easy to interface switches and potentiometers. Now, the only interface is USB. Is there a way to interface a modern USB-based PC joystick to an embedded processor like a PIC or BASIC Stamp without either dismantling the joystick or dealing with USB device drivers?

#2113 **Nick Hulst**
Cedar Rapids, IA

Incandescent Panel Lamp to LED

I need to change a 10 watt 230 volt panel lamp to an LED lamp.

#2114 **Anthony Bogdan**
Cheektowaga, NY

Lithium Batteries

The lithium battery pack on my Ryobi drill suddenly died after a few months of light use. Being a typical *Nuts & Volts* reader, I opened it up expecting to find a bad fuseable link or broken connection. Instead, I saw the requisite number of AA-size batteries and a palm-sized circuit board blanketed on both sides with SMTs plus two hefty, heat-sinked, SCR-looking semiconductors.

I can't expect anyone to analyze the fault without a schematic, which I am unable to obtain. However, my question is: What is the purpose of all the complex electronics? I thought that lithium batteries were simply more powerful versions of NiCads. In fact, I was planning to simply substitute them for the NiCads in an old project. Thoughts?

#2115 **Michael Herman**
La Quinta, CA

Need A CATV Trap or Notch Filter

I'm looking for a trap or notch filter for my inhouse CATV system. I want to filter out just (NTSC) US CATV Channel 111. I'm hoping to find an inexpensive filter since it does not have to be close tolerence or highly specific. I'd be fine with blocking as wide as Channels 108-114.

#2116 **Charlie Smith**
Cedarburg, WI

Flow Meter

I would like to install a flow meter in my agriculture aircraft. The flow meter sets in a two inch housing mounted inline of my spray system. As liquid flows through the housing, it rotates an impeller which produces one 5-volt pulse for every revolution. For the most part, 720 pulses equals one gallon. However, as the specific gravity of the spray solution changes, so does the total pulse count per gallon (i.e., 650 or 780). I would like to be able to preselect total pulses/gal. I figured out how to display a pulse count on a seven-segment display using a 555 timer and LED driver, however, I don't know how to convert it to gallons. Up until now, I've been converting manually by dividing the total pulse count by 720 at the end of the spray pass.

#2117 **Allen Janes**
Eltopia, WA

Bluetooth

I've been experimenting for some time designing models, drawing blueprints, and schematics, and building gadgets. One thing I would like to build is a bluetooth USB transmitter so that when a device is plugged into the USB port, it can transmit and connect wirelessly to a bluetooth dongle.

Also, if you wire the four wires to the circuit board from the output of the USB device, it will allow any wired joystick or composite USB device to operate wirelessly. Any help would be greatly appreciated!

#2118 **Tho Gates**
Austin, TX

>>> ANSWERS

[#11101 - November 2010]
24 Hour Circuit for Electronic Candle

I'm looking for a simple circuit for a 24 hour electronic candle that uses very little power. The candle would

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving technical problems. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals.

Always use common sense and good judgment!

Send all questions and answers by email to **forum@nutsvolts.com**
*Check at **www.nutsvolts.com** for tips and info on submitting to the forum.*

drive a single LED. It would run for x hours (say five), then turn off; 24 hours after it was first activated, it would automatically turn back on for the predefined time.

I've found several ideas, but most of them surrounded the 555 chip which has a very limited time frame.

The PIC16F628 has an internal R/C oscillator. with a 32 kHz option. The current at three volts and 32 kHz is 15 micro-amps, making it perfect for a battery-powered device. The only external components are the LED and a 390 ohm resistor. You write delay loop routines to create a 19 hour loop and a five hour loop for a 24 hour repeating LED.

Dennis Hewett
Frontenac, KS

[#11102 - November 2010]
Fluke Scope and RF

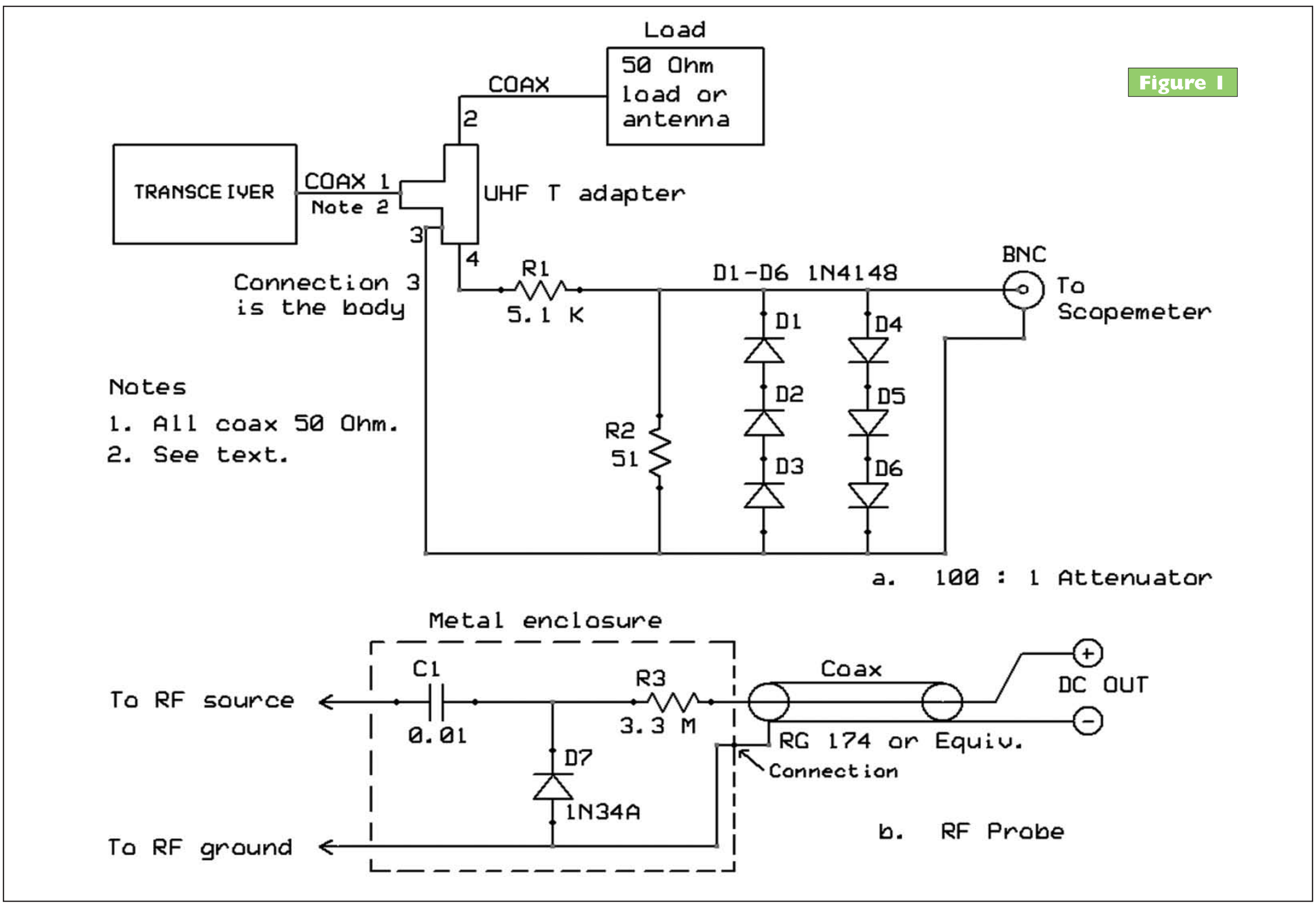
I have a Fluke 99B Series II scopemeter (100 MHz).

I've started working with amateur radio and would like advice on using this scope to measure RF. I think I need an RF probe. I currently have the set of 10:1 probes that come with the scope.

Can the scope — using the proper probes — be used at the actual antenna feed output from the transceiver?

You certainly can use your Fluke scopemeter to work with amateur radios. However, you must be extremely careful if you decide to monitor transceiver output. Most HF transceivers have an output of 100 watts (or more) which can seriously damage your instrument.

Assuming that a transceiver has a 100 watt output — typical for many such units — the output voltage at full power will be 71 Vrms or 99V peak; at 200 watts, the output will be 100 Vrms or 141 Vpeak. Vrms = $(P \times R)^{1/2}$ and Vpeak = $(P \times R)^{1/2} \times 1.4$. Therefore, it is essential to protect the scopemeter and use an attenuator between the transceiver and instrument. A safe approach is to use a 100:1 attenuator while the transceiver is also connected to the proper 50 ohm load as shown in **Figure 1a**. Do ***NOT*** key the transmitter ON without a matching load. For best results, resistors R1 and R2 should be at least 0.5 watts high frequency types. Consider using surface-mount resistors, 2010 size. These resistors have better high frequency



characteristics and a higher withstand voltage which is critical to accommodate the elevated voltages at full power output. Most film type resistors such as RLR or RN series are not suitable for high frequencies above approximately 10-20 MHz (value is also a factor) due to the high parasitic reactance and skin effect of the resistive film. You can use the RLR series resistors if you are willing to accept reduced accuracy. Carbon composition resistors are much better for HF, but they are not very common these days. For simplicity and easy availability, resistors R1 and R2 are 5% values, therefore the attenuation will have a slight error from the ideal 100:1.

For higher accuracy, use 1% resistors, R1 = 5.11K and R2 = 51.1 ohms. Diodes D1 though D6 are used to protect the scopemeter's input and limit the input voltage to approximately ± 4.2 p-p. Make sure to use short wires for all interconnects. This attenuator is suitable for the full frequency response and input levels of your instrument. **Figure 1a** shows a coax between the transceiver and the UHF T adapter.

If convenient, connect the T adapter directly to the transceiver and skip the coax at point 1. The connection between R1 and R2 to the T adapter at points 3 and 4 should be as short as possible, or better yet, use suitable coaxial adapters. The transceiver power output will be:

Power output = (V_{rms}^2 X 100) / Rload or ($V_{p\text{-}p}^2$ /2) / Rload
for a 50 ohm resistive load
Power output = (V_{rms}^2 X 100) / 50 or ($V_{p\text{-}p}^2$ /2) / 50

Note: If you are using the antenna as a load, the equations above may not yield correct results because the antenna may not be an exact 50 ohm resistive match. Please see the ARRL handbook for more details on this subject. Do not use wire-wound resistors; these resistors have high self-inductance and at high frequency, the actual value is higher and reactive.

If you wish to experiment and use an RF probe, **Figure 1b** is a classic basic probe. The minimum detectable input is approximately 0.3 volts and the maximum 30 volts. The common 1N34A germanium diode is preferred for such applications because it has lower forward voltage drop than silicon, has good high frequency characteristics, and is readily available.

The probe should be good to 30-40 MHz. Keep the leads between the probe and the RF source as short as possible. C1 should be a ceramic type and keep all the leads on the RF region as short as possible. Do not use a film type capacitor because it will have high parasitic inductance which will reduce the frequency response. The resistor R3 value and type is not critical because it is on the DC section.

Good luck with your amateur radio hobby.

Mort Arditti, NA6MA
Los Angeles, CA

[#11105 - November 2010]
Using Up Batteries

With so many devices we use today having a power regulator in them, our batteries become ineffective before they really run out of power. What can be done with these batteries that have plenty of life in them, but not enough to get past the power regulator? Is it possible to blink an LED until there is like half a volt or less in each battery? What interesting things can these "dead" batteries do until they are truly dead?

#1 Once a set of batteries is "used up" for widgets that need a certain minimum voltage, I simply toss them in a box and use them for flashlights. They are perfect for bedside flashlights, as they may not be as bright as one with fresh batteries, but perfectly adequate for waking up in the middle of night for nature calls or whatever. Once a flashlight with these batteries starts to go dim, they are truly ready for the recycling bin.

Larry Supremo
Escondido, CA

#2 I have used 'dead' batteries in a cordless headset and battery-operated clocks. A company I worked for used AA batts in their products, so I had more than I could use in the headset. They usually lasted less than two weeks but only took a moment to replace.

The batts I have used in clocks usually last two months or more. Just put them in a clock you can get to easily.

Judd H.
near Reno, NV

#3 I have an LED flashlight that provides more light with a fresh cell than I need. I use used cells, and the flashlight gives enough light for many hours and really runs the cells flat. This particular flashlight uses a voltage boosting circuit to enable it to use just a single 1.5 volt cell.

Michael La Moreaux
Ann Arbor, MI

[#12102 - December 2010]
Garage Door Remote Control

My garage door opener remote operates using a carrier frequency designated W, with modulating frequency 52. Since it is now inoperative (with a fresh nine volt battery), how may I begin to repair or replace either the transmitter or receiver? The manual control connected to the receiver works fine.

I've done a fair amount of electronic circuit design and repair, but nothing in this frequency range which I believe is up in the MHz range.

#1 You didn't state the brand, but your mentioning of carrier W and modulating frequency of 52 Hz makes me think you have a Sears remote and receiver like the ones I've been using, and fixing for some 30 years. The first thing to go wrong with the remote was the pushbutton switch mechanism. It's made of thin spring metal that eventually breaks. As a workaround, I cut two pieces of wire long enough to reach outside the case, soldered them to the board switch terminals, and soldered a general-purpose pushbutton switch to the exposed ends. Take the remote apart and check the switch first. Also, I once found a bad battery connector. Make sure you measure nine volts at the board.

The receiver has stopped working a few times. Each time, I found bad electrolytic capacitors that have dried out and lost their capacitance. Replacing the bad ones usually fixed the problem. If you don't have a capacitor tester, you could just replace all of the electrolytics; there are six in the Sears receiver.

As an aid in troubleshooting, the demodulated 52 Hz tone is coupled back to the antenna for viewing on a scope. You should see a 52 Hz waveform when you press the remote button. You will need to find the circuit return on the receiver board for the scope ground. It should be the negative terminal of the main filter capacitor — usually the largest capacitor in physical size and capacitance. I don't think you'll have to get involved with troubleshooting the RF section.

Marvin Smith
Harbor City, CA

#2 I would not try to repair the original transmitter as most have proprietary chips with no ID numbers.

I would instead check out a transmitter/receiver such as what is listed at **www.seeedstudio.com/depot**. They have a tab for communications, then subtab for wireless on their site.

The transmitter may fit inside the old transmitter case; the receivers have relays which can be connected to the manual button leads on the garage door opener. Many other sites have the transmitters/receivers which are similar, but I have ordered from Seeedstudio in the past successfully.

J.P. McGinley
Stafford, VA

[#12103 - December 2010]
CONAR 251 Scope Info

Where can I find out the value of a fuse for the CONAR Model 251 oscilloscope and/or where can I get a manual or schematic for this scope? (CONAR was bought out by the National Radio Institute - McGraw Hill Continued Education which is no longer in business.) I want to power up this scope and test its output. I need the fuse type and amps before I test it, as money is in short supply. Or, is there a website to find this information?

The fuse in my oscilloscope is labeled "BUSS MDL 1" on one end, "250 VOLT" on the other. The manual says the fuse is a one amp slow blow.

I have two manuals: one is for assembly, the other is for operation. This oscilloscope was part of an NRI course, ca. 1980.

Bob Kottas
via email

Continued from page 29

VISUAL TFT SOFTWARE

Visual TFT from MikroElektronika is a stand-alone application used for rapid development of graphical user interfaces (GUI) for TFT displays. Software generates code compatible with mikroElektronika compilers (mikroC, mikroBasic, and mikroPascal) for all supported MCU architectures: PIC, dsPIC30/33, PIC24, PIC32, and AVR. Software implements an intuitive environment and many drag-and-drop components which can be used for building applications easily and quickly.

Thanks to the power of TFT and TFT Touch Panel libraries, Visual TFT can create complex GUI codes automatically, allowing users to focus on the design of TFT applications.

For more information, contact:
MIKROELEKTRONIKA
Web: **www.visualtft.com**

GRIPPER AND PILLOW BLOCKS

Lynxmotion has been expanding their robotic offerings with a vacuum-powered arm gripper (VAC-KT). This arm attachment utilizes an inexpensive syringe and servo as the vacuum source. The vacuum generated is sufficient to hold a four ounce object for as long as 30 minutes. This assembly is a drop-in replacement for a normal gripper on any of their robotic arms, and can be assembled and installed with common hand tools. Made from high quality laser cut plastic and custom injection molded parts, this unique yet simple device will provide long lasting performance. For use in the classroom, science fair, mad scientist lab, or just for fun, the VAC-KT will make it possible to lift and manipulate small smooth objects with ease. It's priced at $44.95 and comes with everything needed to upgrade an existing arm.

Due to the popularity of their 6 mm pillow blocks, Lynxmotion has expanded the range. They now stock 6 mm, 3 mm, 1/4", and 1/8" versions. These pillow blocks can be the foundation for many small projects that require supporting an axle in one or more places. The heavy duty shielded bearings are rated for 50K RPM. The pillow blocks share common mounting hole spacing and have the same axis height for ease of design. They're made from 6061-T6 aircraft grade aluminum, and priced at $8.95 each.

For more information, contact:
LYNXMOTION
Web: **www.lynxmotion.com**

UNIVERSAL USB CONTROLLER WITH 50 I/O PINS

Saelig Company, Inc. has introduced IO-Warrior56 — a universal USB controller that allows easy access to input or output

functions via a USB bus. Featuring 50 generic I/O lines, IO-Warrior56 is also an I^{2}C/SPI master, allowing users to interface with a wide range of available ICs. IO-Warrior56 offers simple access to the USB since it has been designed as a generic HID device — the protocol is all in the IO-Warrior56 chip. Only a few simple lines of code are needed to access the I/O pins. If you need to connect simple devices to a computer — like relays, switches, a keypad, or a small display — IO-Warrior56 is a simple solution. IO-Warrior56 also supports a range of industrial standard interfaces such as I^{2}C and SPI to simplify interfacing to chips, modules, or displays.

Features include: full speed USB2.0-compliant interface (12 MBit/sec); 50 general-purpose I/O pins, typically 1,000 Hz rate (input or output); I^{2}C master function, 50, 100, or 400 kHz; SPI master interface, up to 12 MBit/sec, throughput up to 62 Kbytes/sec; controls various display modules, including most graphic modules; drives up to 8x64 LED matrix; drives 8x8 switch or button matrix; software support for Mac (10.2 and up), Linux (Kernel 2.6), and Windows (2K/XP/Vista/7); no USB knowledge is needed; single +5V power supply (50 mA operating, 25 µA suspend); 0.1" spaced 56-pin module; and an extended temperature range of -40°C to +85°C. A Development Starter Kit is available for $99.

For more information, contact:
SAELIG
Web: **www.saelig.com**

ADvertiser INDEX

Triple Output Bench Power Supplies

The new CSI3303S & CSI5505S regulated DC power supplies are high reliability, variable DC Power Supplies with built in short circuit and thermal protection. These power supplies are suitable for the laboratory, electronics, communications equipment maintenance, production line, scientific research and educational institutions. Both units are equipped with protection circuits that protect the units from short circuits and over temperature by shutting the unit down for safety. Both units allow independent, serial and parallel mode operation.

Technical Specifications:

Independent mode: 2 independent 0-30V outputs

Series mode: CSI3303S Output from 0-60V & 0-3A
CSI5505S Output from 0-60V & 0-5A
Parallel mode: CSI3303S Output from 0-6A & 0-30V
CSI5505S Output from 0-10A & 0-30V

Both units also provide a 5V fixed output @ 3A

Load regulation: <0.1%+3mV (rating current <3A)
<0.2% +3mA
Ripple and noise: <1mVrms 5Hz-1MHz
<3mArms

Voltage accuracy: +/-0.5%rdg+2byte
Current accuracy: +/-.5%rdg+2byte

Display resolution: +/-0.5%rdg+2byte
Rated output: 5.0V +/-0.1V 3A

Tracking characteristics
Series specifications:
Load regulation: less than 50mV
Ripple and noise: (5Hz~1MHz) <=3mVRMS

Parallel characteristics:
Load regulation: less than 50mV
Ripple and noise: (5Hz-1MHz) CV less than 1mV<=6A), CV less than 1.5mV (I>6A)

Once again Circuit Specialists brings you a quality product at a great price!

Item#
0 to 3A CSI3303S $169.00
www.circuitspecialists.com/CSI3303S
4+ $155.00 ea.

Item#
0 to 5A CSI5505S $194.00
www.circuitspecialists.com/CSI5505S
4+ $179.00 ea.

3 Channel Programmable Regulated DC Power

Check out our new programmable hi preformance 3 channel power supplies. Featuring both USB & RS232 interfaces, Overload Protection, Auto Fan Control, and Series or Parallel Operation. Both units feature a Large LCD display panel with simultaneous output and parameter view and a keypad for control. They are ideal for applications requiring high resolution, multiple output, and automated operation such as in production testing. There are both fine and coarse controls via the shuttle knob and 90 memory settings. Software included.

Reliable, Highly Stable, Fan Cooled.

FEATURES

* Full digital programmable interface
* High resolution 10mV , 1mA
* Compact and lightweight package
* Alterable display mode
* Intelligent window interface Facilitate user operation
* Supports multiple immediate buttons
* Automatic parallel function
* High stability, low drift
* Over-voltage, over-current, over temperature protection
* Intelligent fan control (Changes with output power)
* Warning Alert Buzzer
* 100 memory locations
* RS-232 & USB interfaces standard

Model	CSIPPS33T	CSIPPS55ST
DC Voltage	0-32V x2 0-6V x1	0-32V x2 0-6V x1
DC Current	0-3A x3	0-5A x2 0-3A x1

Item #
CSIPPS33T $479.00
www.circuitspecialists.com/CSIPPS33T

Item #
CSIPPS55T $619.00
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USB Digital Storage Oscilloscopes

* High performance:
* USB connected: Uses USB and supports plug'n play, with 12Mbp communication speed.
* Best performance for your dollar: Thease units have many features that are comparable to the high speedah
stand-alone DSOs. But costs a fraction of the price.
* No external power required: Bus-powered from the host computers USB port.
* Probes & USB cable included.
* Easy to use: Intuitive and easy to understand.
* Various data formats: Can save wavrfrom in the following formats: .txt .jpg .bmp & MS excel/word

40MHz DSO-2090 $169.00
www.circuitspecialists.com/DSO-2090

60MHz DSO-2150 $209.00
www.circuitspecialists.com/DSO-2150

100HMz DSO-2250 $259.00
www.circuitspecialists.com/DSO-2250

200MHz DSO-5200 $299.00
www.circuitspecialists.com/DSO-5200

200MHz DSO-5200A $355.00
www.circuitspecialists.com/DSO-5200A

Specifications	DSO-2090	DSO-2150	DSO-2250	DSO-5200 /5200A
Channels	2 Channels			
Impedence	1M 25pF			
Coupling	AC/DC/GND			
Vertical resolution	8 Bit			9 Bit
Gain Range	10mV-5V, 9 Steps			10mV-10V, 10Steps
DC Accuracy	+/- 3%			
Timebase Range	4ns - 1h 38 Steps			2ns-1h, 39 Steps
Vertical adjustable	Yes			
Input protection	Diode clamping			
X-Y	Yes			
Autoset	30Hz~40MHz	30Hz~60MHz	30Hz~100MHz	30Hz~200MHz
EXT. input	Yes			
Trigger Mode	Auto / Normal / Single			
Trigger Slope	+/-			
Trigger Level Adj.	Yes			
Trigger Type	Rising edge / Falling Edge			
Trigger Source	Ch1 / Ch2 / EXT			
Pre/Post trigger	0-100%			
Buffer size	10K-32K per ch			10K-512KB per ch
Shot Bandwidth	DC to 40MHz	DC to 60MHz	DC to 100MHz	100MHz
Max Sanple Rate	100MS/s	150MS/s	250MS/s	200MS/s / 250MS/s
Sampling Selection	Yes			
Waveform Display	port/line, waveform average, persistence, intensity			
Network	open / close			
Vertical Mode	Ch1, Ch2, Dual, Add			
CursorMeasurement	Yes			
Spectrum Analyzer				
Channels	2 Channels			
Math	FFT, addition, subtraction, multiplication, division.			
Bandwidth	40 MHz	60 MHz	100MHz	200 MHz
Cursor	Frequency, Voltage			
Data Samples	10K-32K/Ch			10K-1M/Ch

We carry a LARGE selection of Power Supplies, Soldering Equipment, Test Equipment, Oscilloscopes, Digital Multimeters, Electronic Components, Metal and Plastic Project Boxes, Electronic Chemicals, PC Based Digital I/O Cards, Panel Meters, Breadboards, Device Programmers, and many other interesting items. Check out our website at:
www.CircuitSpecialists.com

New Year, New Price
CSI-Station1A

Easily our best value in our selection of soldering stations. O.E.M. manufactured just for Circuit Specialists Inc., so we can offer the best price possible! The CSI-Station1A features a grounded tip & barrel for soldering static-sensitive devices and uses a ceramic heating element for fast heat up & stable temperature control.

The control knob is calibrated in Fahrenheit & Celsius (392° to 896°F and 200° to 480°C). One of the nicest features is the high quality comfort grip soldering iron. The iron connects to the station via an easy screw-on connector making iron replacement a snap. The 1 meter length iron cord provides plenty of length for users to set up the station in a convenient location. Another nice feature is the soldering iron holder. Made of rugged aluminum,it is a seperate piece from the main station & allows the user maximum convenience.....you don't have to reach all the way back to the station to store the iron. Yet another feature is the stackable design of the CSI-Station1. The main station is designed for an additional unit to be placed on top of it allowing for space saving placement of the CSI-Station1A. Also included at no additional charge is one user replaceable ceramic heating element so that you will be prepared! Large selection of soldering tips available too.

Item# CSI-STATION1A **$29.95**

www.circuitspecialists.com/csi-station1a

Programmable DC Electronic Loads

Thease devices can be used with supplies up to 360VDC and 30A. It features a rotary selection switch and a numeric keypad used to input the maximum voltage, current and power settings. These electronic DC loads are perfect for use in laboratory environments and schools, or for testing DC power supplies or high-capacity batteries. It also features memory, and can also be connected to a PC, to implement remote control and supervision.

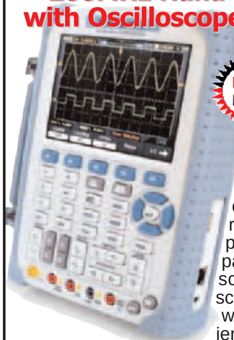
360V/150W (CSI3710A) $349.00

www.circuitspecialists.com/csi3710a

360V/300W (CSI3711A) $499.00

www.circuitspecialists.com/csi3711a

200MHz Hand Held Scopemeter with Oscilloscope & DMM Functions



NEW ITEM

Includes 1 Year USA Warranty

You get both a 200 MHz Oscilloscope and a multi function digital multimeter, all in one convenient lightweight rechargeable battery powered package. This power packed package comes complete with scopemeter, test leeds, two scope probes, charger, PC software, USB cable and a convenient nylon carrying case.

- 200MHz Handheld Digital Scopemeter with integrated Digital Multimeter Support
- 200MHz Bandwidth with 2 Channels
- 500MSa/s Real-Time Sampling Rate
- 50Gsa/s Equivalent-Time Sampling Rate
- 6,000-Count DMM resolution with AC/DC at 600V/800V, 10A
- Large 5.7 inch TFT Color LCD Display
- USB Host/Device 2.0 full-speed interface connectivity
- Multi Language Support
- Battery Power Operation (Installed)

Item # DSO1200 **$739.00**

www.circuitspecialists.com/DSO1200

60MHz Hand Held Scopemeter with Oscilloscope & DMM Functions

- 60MHz Handheld Digital Scopemeter with integrated Digital Multimeter Support
- 60MHz Bandwidth with 2 Channels
- 150MSa/s Real-Time Sampling Rate
- 50Gsa/s Equivalent-Time Sampling Rate
- 6,000-Count DMM resolution with AC/DC at 600V/800V, 10A
- Large 5.7 inch TFT Color LCD Display
- USB Host/Device 2.0 full-speed interface connectivity
- Multi Language Support
- Battery Power Operation (Installed)

Item # DSO1060 **$529.00**

www.circuitspecialists.com/DSO1200

60MHz Hand Held Scopemeter w/Oscilloscope, DMM Functions & 25 MHz Arbitrary Waveform Generator

- All the features of the DSO1060 plus a 25 MHz Arbitrary Waveform Generator.
- Waveforms can be saved in the following formats: jpg/bmp graphic file, MS excel/word file
- Can record and save 1000 waveforms
- DC to 25 MHz Arbitrary Waveform Generator

Item # DSO-8060 **$659.00**

www.circuitspecialists.com/DSO-8060

Programmable DC Power Supplies

- Up to 10 settings stored in memory
- Optional RS-232, USB, RS-485 adapters
- May be used in series or parallel modes with additional supplies.
- Low output ripple & noise
- LCD display with backlight
- High resolution at 1mV

Model	CSI3644A	CSI3645A	CSI3646A
DC Voltage	0-18V	0-36V	0-72V
DC Current	5A	3A	1.5A
Power (max)	90W	108W	108W
Price	$199.00	$199.00	$199.00

Rack Mount Power Supply

www.circuitspecialists.com/BTI-150

The BTI-150 is a high efficiency switch-mode power supply designed to be rack mounted in a standard 19" rack mount enclosure. This rack mount power supply has a front panel switch which allows the user to select three different variable DC voltage outputs. Output one allows for voltages from 0 to 15 volts DC and an output current from 0-10Amps Output two allows for voltages of 0-30 Volts DC and 0 to 5 amps while the final output position provides for output voltages of 0 to 60 volts DC at 0 to 2.5. Amps.

The outputs are all displayed on the front panel led displays. The 1U design makes this rack mount power supply ideal for high use application areas. Multiple supplies can easily be stacked in the rack mount configuration. Additionally, the user has the option of removing the front panel mounting ears if a bench top application is preferred.

This rack mount power supply provides a versatile solution to many applications. The 1U dimension (19in (48cm) width & 1.75in (4.45cm) height allows the end user a broad selection of DC voltage outputs with minimal impact on the total size capacity of the rack mount enclosure.

Output Voltage	Output Current	V/C Display	Resolution
0~15V	0~10A	Digital	0.1+/-2digit
0~15V	0~5A	Digital	0.1+/-2digit
0~15V	0~2.5A	Digital	0.1+/-2digit

New Lower Price!
Item# BTI-150 **$129.00**

0-30V / 0-5A . DC Power Supply

The CSI530S is a regulated DC power supply which you can adjust the current and the voltage continuously. An LED display is used to show the current and voltage values. The output terminals are safe 4mm banana jacks. This power supply can be used in electronic circuits such as operational amplifiers, digital logic circuits and so on. Users include researchers, technicians, teachers and electronics enthusiasts. A 3 ½ digit LED is used to display the voltage and current values.

www.circuitspecialists.com/csi530s

Item # CSI530S **$84.95**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