PROJECTS ■ THEORY ■ APPLICATIONS ■ CIRCUITS ■ TECHNOLOGY

NUTS AND VOLTS

www.nutsvolts.com
April 2011

EVERYTHING FOR ELECTRONICS

BUILD THE STROBOSCOPIC ZOETROPE

The 32-Bit Experimenter Gets a USB Hardware Interface

✦ **Mixed Voltage Systems**
Interfacing 5V and 3V Devices

✦ **True-Reading Gas Gauge**
Upgrade your old float style gas gauge with a true-reading flow meter type.

✦ **PICAXE Primer**
Experimenting with capacitive-touch sensors.

✦ **Open Communication**
Is there a wireless frequency spectrum crisis?

U.S. $6.50 CANADA $7.50
04
0 71486 02421 7

Vol. 32 No. 4
NUTS & VOLTS
ZOETROPE • GAS GAUGE • 32-BIT EXP USB • MIXED VOLTAGE SYSTEMS
April 2011

PIC32

WaveAce™ Oscilloscopes
40 MHz – 300 MHz
WaveJet™ Oscilloscopes
100 MHz – 500 MHz
WaveSurfer® MXs-B &
Mixed Signal Oscilloscopes
200 MHz – 1 GHz
ArbStudio
Arbitrary and Digital Pattern
Generators
LogicStudio™
USB Logic Analyzer

Nuts & Volts
April 2011
www.nutsvolts.com


Page 36

Projects & Features

Departments

Columns


Page 10

Nuts & Volts (ISSN 1528-9885/CDN Pub Agree #40702530) is published monthly for $26.95 per year by T & L Publications, Inc., 430 Princeland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: Send address changes to **Nuts & Volts, P.O. Box 15277, North Hollywood, CA 91615** or Station A, P.O. Box 54, Windsor ON N9A 6J5; cpcreturns@nutsvolts.com.

DEVELOPING PERSPECTIVES

Designing For Others

If you've ever designed and built an electronic gizmo for someone else, you know that once the device leaves your sight, anything goes. For this past holiday season, I built a small robot for my nephew using an Arduino processor, a separate linear power regulator, and a few sensors. The robot didn't last a week. The culprit — an eight year old — had reversed the polarity of the 9V battery, permanently frying the microprocessor's on-board regulator circuit. Fortunately, I was able to rework the board, and the other components connected to the separate regulator weren't affected.

It hadn't occurred to me that anyone, of any age, could have reversed the battery inadvertently. Before handing the robot back to my nephew, I inserted a series diode to guard against future polarity mix-ups. The cost – about a 0.7V drop across the diode – was reasonable in the low power circuit.

The point to this story is that designing for others demands that you pay attention to what could go wrong. Expect that your creations will be dropped, dunked, and rained on. Assume that someone will try to plug power into the audio output jacks, and that the power is either the wrong polarity or voltage.

If you're an engineer working in a large company, you might have a quality control group and human factors team to pour over your creations. However, when you're a one-person shop, your designs have to reflect usability from day one. Reasonable design considerations and fixes include:

- Assume the user will eventually forget what the various switches and LEDs are used for or signify. Label everything.
- Count on the user confusing what plugs into what. Minimize this possible confusion by using unique connector types for each input and output.
- Recognize that to many people, one power brick looks like any other. Design your power supplies to handle a wide range of inputs, as well as reverse polarity. In addition, label the power brick that goes with your gizmo.
- Assume your creation will be drop-kicked and land in a puddle. If you use plastic cases, buy the type with built-in bushings to avoid stripped plastic. Also, use strain relief on battery connectors and power cords. I also like to use locknuts instead of plain nuts and loose lock washers.
- Ventilation is rarely optimal. If space and money allow, overdesign heatsinks and cooling fans by 50% or more. Consider using an oversized cabinet over a smaller cabinet with forced air ventilation.

Of course, getting everything technically correct doesn't guarantee your gizmo will be useable by your intended user. Basic ergonomic issues also apply. For example, if you've developed a phone dialer for your elderly parents or grandparents, use big, well illuminated, easily depressed buttons. Similarly, if you've developed a toy, use knobs that can't be dislodged and swallowed, and make certain there are no pinch points to trap tiny fingers.

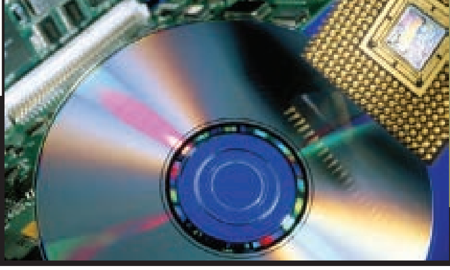
Designing for others is both challenging and fun. You'll get an immense sense of satisfaction from taking a circuit from exposed perfboard to printed circuit board and slick enclosure, and — more significantly — from having your creation bring enjoyment to others. **NV**

NUTS AND VOLTS

EVERYTHING FOR ELECTRONICS

Published Monthly By
T & L Publications, Inc.
430 Princeland Ct.
Corona, CA 92879-1300
(951) 371-8497
FAX **(951) 371-3052**
Webstore orders only **1-800-783-4624**
www.nutsvolts.com

Subscriptions
Toll Free **1-877-525-2539**
Outside US **1-818-487-4545**
P.O. Box 15277
North Hollywood, CA 91615



TECH KNOWLEDGEY 2011

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

GRAPHENE OUT, MOLYBDENITE IN?

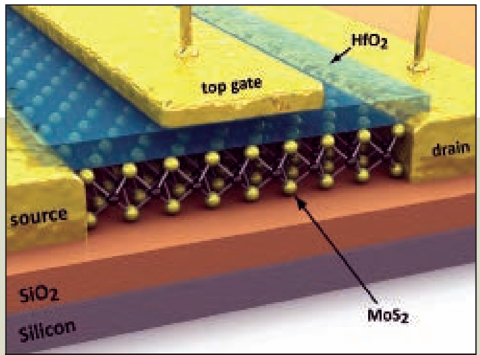


Photo courtesy of EPFL.

■ Illustration of molybdenite integrated into a transistor.

It's no secret that we are reaching the limits of silicon semiconductor technology, and there have been years of speculation about possible replacement materials. One highly touted one is graphene which is basically a one-atom-thick sheet of carbon atoms arranged in a honeycomb crystal lattice. Back in 2008, a Columbia University researcher explained, "Graphene behaves almost like semiconductor but without an energy gap. This is why it would do well as a material for computer chips." In fact, the material looked so promising that the University of Manchester physicists who discovered it received the 2010 Nobel Prize in Physics.

Hang on though, because it looks like that lack of an energy gap is not necessarily such a great thing after all. After quite a bit of study, an IBM Research scientist recently noted, "There is an important distinction between the graphene transistors that we demonstrated and the transistors used in a CPU. Unlike silicon, graphene does not have an energy gap, and therefore graphene cannot be switched off, resulting in a small on/off ratio." A transistor with no off state is about as useful as a faucet that is always open, so the concept of graphene as a complete replacement for silicon seems less promising at present.

Earlier this year, researchers at the École Polytechnique Fédérale de Lausanne (EPFL, **www.epfl.ch**) noticed that another material could have serious advantages over both silicon and graphene in electronics applications. The material is molybdenum disulfide, or molybdenite (MoS_2) which is a bit like graphite and is used in steel alloys and lubricants. Apparently, electrons can move as freely in a 0.65 nm thick sheet of MoS_2 as in a 2.0 nm sheet of silicon. Plus, it can be used to fabricate transistors that consume 100,000 times less energy in standby state than silicon devices. According to EPFL, "A semiconductor with a gap must be used to turn a transistor on and off, and molybdenite's 1.8 electron-volt gap is ideal for this purpose." The material is also said to hold great promise for the fabrication of LEDs and solar cells. No one can be certain which material — or perhaps yet another — will end up in the electronics of the future, but it should be an interesting race. ▲

PLATOONING PASSES FIRST TEST

■ An autonomous Volvo follows the lead vehicle in a demonstration of the SARTRE concept.

Since 2009, with orchestration by Ricardo UK Ltd., a collaboration of several European companies has been developing a concept dubbed Safe Road Trains for the Environment, loosely abbreviated SARTRE. The goal is to develop vehicles that can drive themselves in long road trains, improving traffic flow, shortening travel time, increasing driver comfort, reducing accidents, and improving fuel consumption. Under the concept — also known as "platooning" — a convoy of cars will follow a lead vehicle with each drone car measuring the leader's distance, speed, and direction, and automatically adjusting its own operation. The driver is then free to relax, read the newspaper, and possibly knock down a few cocktails. Anyone can leave the convoy at any time.

The first demonstration of the system with real vehicles rather than simulators took place on January 17 at the Volvo Proving Ground outside of Gothenburg, Sweden, and the development teams reported a rousing success. The concept is not without obstacles, however. For one thing, developers must first overcome such issues as enacting necessary and similar laws in 25 different EU countries and developing redundancy to handle primary system failures. In addition, no explanation was offered regarding the effects of an operating road train on other vehicles. How can nonparticipants enter the roadway when platoon cars are only a few meters apart? How can a solo driver pass a long convoy safely? And because everyone must follow the leader, how do you avoid ending up with 100 cars pulling up to the same restroom at the same time?

Will SARTRE be a boon or a boondoggle? Time will tell. The system is planned for general implementation within a decade. Perhaps it's significant that the name invokes the memory of an idiosyncratic existentialist who, among other things, declared Fidel Castro "the era's most perfect man." ▲

COMPUTERS AND NETWORKING

DESKTOP PERFORMANCE IN A PORTABLE

A few weeks ago, NextComputing introduced the Radius EX, an all-in-one workstation designed to provide desktop-class performance in a portable machine. This certainly bucks the trend in an era of laptops and notebooks, and is hugely reminiscent of the old Kaypro and Osborne computers. The company wants to appeal to a different class of customers, typically including "sports broadcasters, film and video content producers, telecom service providers, radiologists, and enterprise software companies." If you are among these, be advised that the EX offers a 17 inch 1920 x 1200 display, an aluminum alloy chassis with padded leather handle, a choice between a single Intel Core i7 processor (up to 3.33 GHz) or dual Xeon 5600 units (up to 2.26 GHz), seven PCI expansion slots, 48 GB of RAM, and more than 7 TB of internal SATA or SAS drive storage. The spec sheet doesn't mention the unit's weight, but the fact that a rolling case is an option might offer a hint. Prices were not provided, but you can get a quote at **www.nextcomputing.com**. ▲

■ NextComputing's Radius EX all-in-one portable.

EASTER CONNECTION TO EXTERNALS

■ NewerTech's adapter provides faster external drive access.

If you bought yourself a new computer that's equipped with the new "SuperSpeed" USB 3.0 interface and an eSATA external or two, NewerTech (**www.newertech.com**) has a deal for you. Introduced at MacWorld 2011 (but compatible with PCs, as well) is the company's eSATA to USB 3.0 adapter which it claims offers benchmark-proven reads at 247.0 MB/s and writes at 206.4 MB/s, which is up to six times as fast as other interfaces. Firewire 800, for example, provides 81.8/78.6 MB read/write times, and USB 2.0 is even slower at 38.4/32.2 read/write times. The adapter requires OS X 10.2.8 or later, or Windows 2000 or later. It supports 2.5 and 3.5 inch hard drives, and SSDs and hot swap. The list price is $29.95. ▲

FREE PASCAL COMPILER

It's not for everyone, but if you (1) write code for the 8051 family of microcontrollers and (2) like Pascal, you'll be glad to know that a free Pascal compiler is available from **www.turbo51.com**. Turbo51 uses Borland Turbo Pascal 7 syntax and is applicable to both hobby projects and serious work. According to the site, "If you are already familiar with 8051 assembly language programming, you can start with Turbo51 as an 8051 assembly language compiler and then add some Pascal statements until you become familiar with Turbo51 and Pascal syntax. A good approach is also to compile some Pascal code and then check generated code (ASM file). This way, you can learn assembly language, get some ideas on how to write effective code, and become familiar with the compiler." Turbo51 is released as freeware but, of course, users are encouraged to make a small donation via PayPal. Developer Igor Funa says he has some bills to pay. ▲

CIRCUITS AND DEVICES

GIVE YOUR HANDHELDS A CHARGE

It might be a little fluffy to present it as "the world's first passive kinetic energy charger for hand-held electronic devices," but Tremont Electric's nPower® PEG (personal energy generator) is a neat little device. PEG is a backup battery charger for cell phones, iPods, GPS units, etc., that rides in a backpack, purse, or other part of your wardrobe, and taps into the energy you expend when walking, running, or biking. Think of it as a descendent of the self-winding watch. Interestingly, not only is the unit made in the USA, 90 percent of its components come from the state of Ohio, which may explain why it's $159 instead of $49.95. Even so, they're back-ordered as of this writing, so Cleveland must be more popular than a lot of people think. You can reserve one at **www.npowerpeg.com**. ▲

■ The nPower PEG harnesses your kinetic energy to charge hand-held devices.

HD VIDEO RECORDER INTRODUCED

The good news is that if you want to watch, record, and edit HD cable and satellite TV, there is now EyeTV HD — a full featured DVR that links your computer to a cable or satellite receiver. The bad news is that it is available only for Macs, so if you're a PC, you're out of luck. But don't feel too bad. If you own an older Mac, you're still out of luck. Minimum system requirements include a 2.26 GHz Intel Core 2 Duo processor and OS X 10.5.8 or later. The unit, marketed by Elgato (**www.elgato.com**), comes with an IR remote and channel change cable (known as the "IR blaster") for control of the receiver. It also offers a dual-format capture mode that records in iPad and iPhone formats at the same time, offers exports to iTunes, and facilitates streaming to both iPad and iPhone via an optional app. It includes cables for component, composite, S-video, and stereo audio, plus a one year subscription to *TV Guide*. List price is $199.95. ▲

■ Elgato's EyeTV HD, a DVR for Macs.

INDUSTRY AND THE PROFESSION

TOP 10 OEMS BUY $104 BILLION OF CHIPS

According to market researchers at Gartner, Inc. (**www.gartner.com**), the plethora of new electronic products from new companies hasn't caused much diffusion in the chip market. In 2010, the top 10 original equipment manufacturers (OEMs) accounted for one third of worldwide semiconductor vendors' revenues. Overall sales were up $26 billion from 2009, a 33.7 percent increase, so things looked rosy in that respect. The growth drivers were predominantly mobile PCs, smartphones, and LCD TVs. The top three purchasers were HP, which ate up $17 billion worth of silicon (up 32 percent); Samsung, with $15 billion (up 31 percent); and Apple, with $12.5 billion (up 65 percent). Next on the list are Nokia, Dell, Sony, Toshiba, LG, Panasonic, and Lenovo, in that order, for a total of $104 billion. When you add in the "all others" category, total worldwide semiconductor revenues came to a bit over $300 billion. **NV**

PICAXE PRIMER

SHARPENING YOUR TOOLS OF CREATIVITY

■ BY RON HACKETT

EXPERIMENTING WITH CAPACITIVE-TOUCH SENSORS

In the previous installment of the Primer, we experimented with a couple of variations of touch-sensitive keypads. This month, we're going to focus on two less orthodox applications for the PICAXE capacitive-touch sensors. First, we'll implement a simple water detection system that's capable of responding to a single drop of water on the sensor. Then, we'll experiment with measuring the amount of water in a container.

Before we get started, I have two pieces of "old business" that I need to discuss. First, back in the June '09 column (*Taming Unruly LCDs, Part II*), there was an important mistake in the schematic for the project; somehow I managed to reverse the power and ground connections (pins 1 and 2) on the 16-pin LCD header! Several months ago, a reader emailed me about that mistake, and I mentioned the error in a subsequent column. However, I recently received an email from another reader who spent a fair amount of frustrating time on the project before he realized that the schematic was wrong.

Obviously, mentioning my error in a subsequent column isn't an effective way of dealing with the problem, so I have decided to include a PICAXE Primer Errata Listing on my website as well as the *Nuts & Volts* site. In it, I'll include a corrected version of the LCD schematic, and any other corrections that are brought to my attention in the future. Hopefully, it won't become a long list, but at least the necessary corrections will all be in one place. I'll mention it from time to time in this column to encourage you to check it out if you're having a problem with a project.

The second piece of "old business" relates to resource materials on the topic of capacitive-touch sensors. In the previous column, I mentioned a Microchip Application Note that helped me understand various aspects of working with capacitive-touch sensors. Since that time, I have found additional app notes that are also relevant. Some of the information contained in the following list of notes is very technical, but there is also a fair amount of practical information that you may find helpful:

- AN1101: Introduction to Capacitive Sensing
- AN1102: Layout and Physical Design Guidelines for Capacitive Sensing
- AN1103: Software Handling for Capacitive Sensing
- AN1104: Capacitive Multi-button Configurations

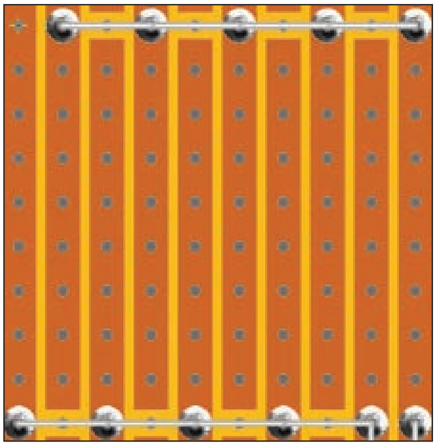
If you are interested in any of this material, just go to **www.microchip.com** and search for "AN1101" or whichever publication interests you.

WATER, WATER EVERYWHERE

Okay, we're ready to get into our first topic: water detection. For my first experiment in this area, I simply dribbled a little water on a small stripboard touch sensor while I was running a program that transmitted the *Touch* values to the Terminal Window. Unfortunately, this approach didn't work; even though the value consistently changed in response to a finger touch, a drop of water had no effect at all.

In order to understand what was happening, I spent some time reading through the four app notes just listed. In a couple of places, Microchip emphasizes the importance of physically separating the sensors from ground. For example, on a printed circuit board (PCB), they strongly recommend that ground planes not be included underneath a sensor element, and that no ground traces should run near or between sensor elements. They also state that failing to take these precautions can lead to confounded sensor readings. Because I didn't clearly understand what that meant, I decided to break the "rule" to see what would happen. (Don't you just love it when you get to break a rule?) To do so, I made a simple stripboard sensor that interleaved the sensor and ground traces.

Figure 1 shows the bottom view of the stripboard layout that I used. The board is used "upside down," and nothing at all is installed on the



■ FIGURE 1. Stripboard layout for a simple water detector.

non-trace side. (Actually, that's not quite true. When I first dribbled water on the sensor, it ran through the holes in the stripboard, and soaked into the papers strewn about my desk, so I dried it off and affixed a piece of packing tape to the non-trace side. You may want to do the same, and it would certainly be easier to do before the board gets wet!)

In the bottom-right corner of the layout, you can just see the ends of the two jumper wires that extend from the stripboard. Either of the jumpers is inserted in the breadboard's ground rail, and the other jumper is inserted so that it's connected to pin B.4 (or any other touch input) on the 18M2.

If you follow the connections in **Figure 1**, you will see that every other trace on the stripboard is connected to one of the two jumpers, and the remaining traces are connected to the other jumper. As a result, whenever a drop of water hits the board, it will make contact with both the sensor input and ground.

Figure 2 shows the photo of my completed breadboard circuit which is simple enough not to require any additional explanation. The software that I used for this experiment (*WaterDetector.bas*) is available on the *N&V* website, along with the other programs that we'll be using this month. The program implements a simple do-loop that just sends the touch reading to the Terminal Window:

```
do
        touch sensor, value
        sertxd (#value, HT)
loop
```

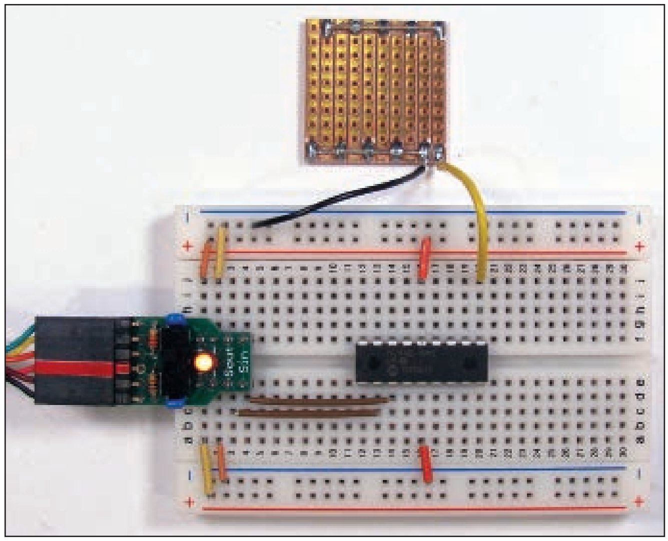
HT is a constant that I set equal to 9 which is the ASCII character for a horizontal tab; it just puts a little space between consecutive bytes in the Terminal Window to improve readability.

When I first ran the program, I was in for a little surprise; the value displayed in the Terminal Window was consistently 255. From reading the Microchip app notes, I already knew that the obtained touch value is proportional to the amount of capacitance that the touch command is measuring between the sensor line and the ground plane. Since 255 is the maximum byte value, I assumed that the capacitance was already at or above the maximum value that the touch command can process — probably because I broke the rule!

To test this assumption, I pressed the sensor several times with my finger; the value didn't change at all. However, when a mechanical switch doesn't work for me, I have a tendency to press it frequently and with a fair amount of pressure. I guess that's become a habit, because before I realized it, I was doing the same thing to the touch sensor.

Surprisingly, if I pressed very hard on the sensor, the value in the Terminal Window abruptly changed from 255 to 0. My guess is that this phenomenon is one of the ways that the proximity of ground and sensor lines can confound the capacitive readings. Most likely, very hard finger presses reduce the resistance between ground and the sensor to a point where sufficient current is flowing between them to disrupt the functioning of the touch reading.

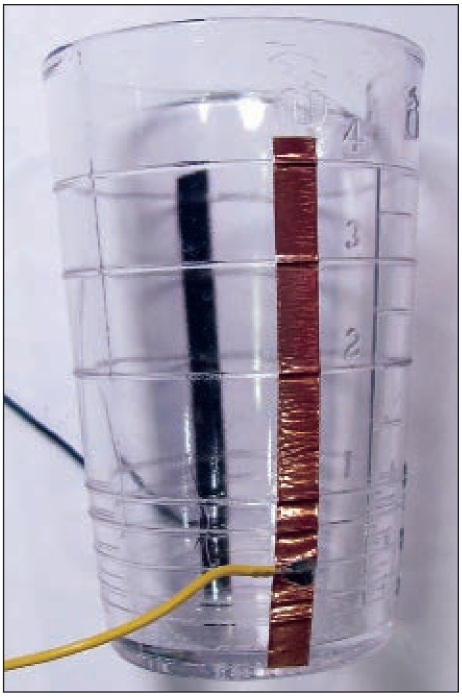
My first thought was that my rule-breaking behavior might have damaged pin B.4 on the 18M2; my second thought was that a little water probably wouldn't do any more damage, so I used a small squeeze bottle to place a single drop of water on the sensor. Again, the value in the Terminal Window abruptly changed from 255 to 0. When I blotted it off with a tissue, the value immediately jumped back to 255. I repeated that process several times, and the value consistently went from 255 to 0, and back again.



■ FIGURE 2. Breadboard setup for the water detector.

As a water detector, the circuit seemed to be extremely reliable, but I was still worried about the possibility of damaging the 18M2, so I posted a question on the PICAXE forum. In less than 20 minutes, I had a reply from "Technical" — an official PICAXE expert on the forum. He explained that a 0 value is a result of the touch command timing out, and "it shouldn't damage the chip in any way." Of course, I may find some other way to damage the 18M2 before I'm done, but Technical's reply encouraged me to keep on experimenting.

In case you've been wondering, I entitled this section "Water, Water Everywhere" because in the middle of my experimentation, I managed to spill a fair amount of water on my Mac's keyboard. After a brief encounter with a hair dryer, it too seems to have survived my experiments — at least so far. If you decide to build and experiment with the water detector circuit, you may want to clear a little more space on your desk (and exercise a little more caution) than I did.



■ FIGURE 3. Glass beaker prepared for Water-Level Experiment #1.

HOW MUCH WATER IS THERE, JOHNNY?

Encouraged by my success with the water detector, I next decided to tackle the problem of measuring the level of water in a container. Based on what I had already learned, I knew that I couldn't allow the water to come in contact with either the sensor line or ground plane of the circuit, so I decided to place two sensors opposite each other on the outside of the container for this experiment. Fortunately, I already had a product on hand that was perfect for this application.

I had accidentally discovered it a few weeks earlier, when I was searching the Web for the thin copper tape that can be used to correct a mistake on a PCB by adding a missing trace. As I was searching, I came across Stewart-McDonald (**www.stewmac.com**), a company that specializes in supplies for building and repairing stringed instruments. One of the products that they sell is a self-adhesive conductive copper tape that's used to shield electronic pickups to reduce hum, noise, and radio interference in amplified musical systems.

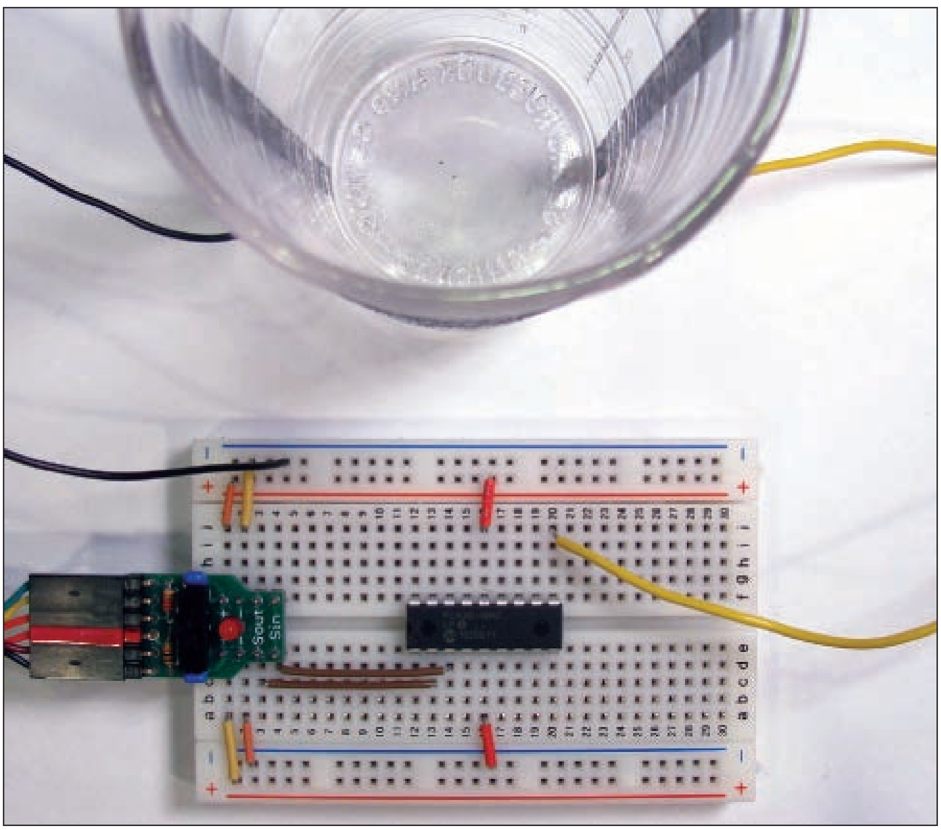
The tape comes in three widths (1/4, 3/4, and two inches) and the best part (for our purposes) is that the "self-adhesive backing is also conductive, so overlapped seams are electrically continuous." If you're interested, go to their website and search for "0038" which is the relevant part number.

Figure 3 is a photo of the four ounce glass beaker that I used for this project. (You could just as easily use a plastic or glass measuring cup or a water glass.) For the sensor and ground, I used the 1/4 inch copper tape, but two thin strips of aluminum foil taped to opposite sides of the vessel should also work. In the photo in **Figure 3**, you can see where I soldered a jumper wire to one of the pieces of tape. (The connection to the piece of copper tape on the rear of the beaker is the same.) To avoid the possibility of cracking the glass, it's best to do the soldering before you attach the tape to the glass. I tried soldering a wire to aluminum foil, but it didn't work. If you use aluminum foil, you will need two jumper wires with small alligator clips to make the necessary connections to the foil strips.

Figure 4 is a photo of the breadboard setup I used for this experiment. In it, you can see that I have bent the two leads that connect the beaker to the breadboard so that they are as far away from each other as possible. I did this because I discovered that it results in lower overall touch values which makes sense because the closer the wires, the greater the capacitance between them. (We'll soon see why lower values are desirable.)

For our first experiment with the water level sensor, we'll use the same program that we used previously (*WaterDetector.bas*). When I first ran the program, the beaker was empty, and the touch value vacillated between 112 and 113. (Make sure to keep your hands at least six inches away from either wire; anything closer than that results in elevated values.) Next, I added water in one-ounce increments, and obtained the results presented in **Figure 5**.

As you can see, there's clearly a direct relationship between the amount of water in the glass and the corresponding touch value. Of course, the touch values that I obtained are all slightly inaccurate because I added the water "by eye," so my increments



■ FIGURE 4. Breadboard setup for Water-Level Experiment #1.

weren't exactly one ounce each. In spite of that, the relationship is clear. Also, the fact that four ounces of water produced a value almost equal to 255 indicates that four ounces is about the maximum volume that can be measured with our current setup; that's why I said earlier that lower readings are desirable. (In our next experiment, we'll find a way to increase the maximum volume of water that can be measured.)

If you run the experiment more than once, make sure you dry the glass thoroughly between trials. Even a few drops of water on the interior of the container will slightly elevate the value for zero ounces. Also, emptying and drying the glass will inevitably move the leads somewhat, so you aren't likely to get exactly the same results twice.

If you examine the data presented in **Figure 5**, you will see that the relationship between the volume of water and the *touch* value isn't linear; the increments gradually decrease as the amount of water increases. I think that's because my little beaker is wider at the top than it is at the bottom, so the two strips of tape are further apart at the top of the beaker. My guess would be that a perfectly cylindrical container would produce more linear results, but I couldn't find a suitable container to test that assumption. If you have one on hand, you may want to see if that's the case. If you do, send me an email to let me know what you discover.

In order to modify our program to output a measure of the number of ounces of water in the container, we need to add a *select case* statement that uses the midpoints obtained in **Figure 5**:

```
select case value
         case < 134
          level = 0
         case < 173
          level = 1
         case < 206
          level = 2
         case < 237
          level = 3
         else
          level = 4
       end select
```

Of course, we also have to add a variable for *level* and change the *sertxd* command appropriately. The program that I used (*WaterLevelOunces.bas*) is also available for downloading at the *N&V* website.

■ FIGURE 5. Results for Water-Level Experiment #1.

Ounces	Touch Value
0	112-113
1	156-157
2	190-191
3	222-223
4	251-252

Increment	Mid-Point
44	134
34	173
32	206
29	237

Our first water level program functions very well, but it has a major limitation: the largest amount of water it can measure is four ounces. As you may remember from the previous column, it was my espresso machine that prompted me to explore the possibility of using the PICAXE capacitive-touch sensors to measure the level of water in its tank. Since that tank holds several cups of water, our present approach is clearly not up to the task. The solution to this dilemma is to switch to the *touch16* command, because its optional *config* parameter can provide us with a considerable amount of control over the range of capacitance that can be measured by the command.

Unfortunately, more powerful commands also tend to be more complicated, and the *touch16* command is definitely not an exception to the rule. (At this point, it probably would be a good idea to read the documentation on the touch16 command in Section 2 of the PICAXE Manual.)

In order to experiment with the possibility of reliably measuring the level of larger amounts of water, I used an eight-cup measuring cup with two strips of copper tape installed on the outside in the same manner that I described for my four ounce beaker. My plan was to experiment with changing the value of the *config* parameter of the *touch16* command until I was able to measure the water level with a reasonable amount of accuracy. To begin with, bits 7-5 of *config* determine how many oscillations are required to carry out a *touch16* command. It seemed reasonable to me to assume that a faster command would produce a lower reading which, in turn, would allow for the measurement of larger volumes of water. Therefore, my first attempt to measure larger volumes of water involved setting those three bits of *config* to "111."

How the remaining five bits of *config* (bits 4-0) would affect the reading wasn't as clear to me, so I decided to manipulate them experimentally. In other words, I took a classic trial-and-error approach to see whether I could find a combination that worked effectively. I'm not going to discuss the details of all the values that I tested along the way, but I did eventually find that a *config* value of %11111111 produced the results that I was hoping for.

The final program that worked for me (*WaterLevelLarge.bas*) is also available on the *N&V* website. If you want to duplicate my experiment, download it and try it out with a larger water container. I did include one additional command in the program that may require some explanation. Because the t*ouch16* command uses a word variable, the returned value can be as large as 65,535. Of course, larger readings also produce a wider variance in the value produced for each water level.

On the other hand, smaller readings minimize the variance for each level, but the readings for adjacent levels are also closer together which makes it more difficult to determine the correct level for each reading. In order to find a workable compromise between these two extremes, I experimented with dividing the resulting readings by a constant to scale them down somewhat. I tried several different constants, and finally settled on

Cups	Touch Value	Increment	Mid-Point
0	598	45	621
1	643	15	651
2	658	18	667
3	676	16	684
4	692	12	698
5	704	17	713
6	721	12	727
7	733	9	738
8	742		

■ FIGURE 6. Results for Water-Level Experiment #2.

dividing the resulting value by four. For my setup, this scaling factor resulted in a reasonable range of values that were also reliable at each water level that I measured.

Figure 6 shows the results that I obtained by using the *WaterLevelLarge.bas* program with my eight-cup measuring cup. As you can see, the values are sufficiently spread out to easily discriminate the level of water in the container (in one cup intervals), and the maximum value (742) is low enough to allow for using the same approach with much larger containers.

The only minor anomaly in the results is that the difference between the values I obtained for one and zero cups is significantly greater than any of the other adjacent levels. This discrepancy may have been caused by the fact that the glass at the bottom portion of the measuring cup that I used was rounded inward. I guess I will need to find a large cylindrical container to test that assumption, as well.

Similarly to the approach we took in *WaterLevelOunces.bas*, it would be a simple matter to use the mid-points presented in **Figure 6** to add a *select case statement* to the *WaterLevelLarge.bas* program, so that it would output a measure of the number of cups of water in the container. That program is **not** available for downloading, but you may want to give it a try.

WE'RE NOT DONE YET!

That's all for this time, but I still have at least one more application of the 18M2's capacitive-touch sensors that I want to discuss. I have been experimenting with the possibility of using a touch sensor underneath a doormat or other small carpet to determine when someone is standing on or has walked across the carpet. I know there are commercially-available mats that do the same thing, but they tend to be expensive, and it's much more fun to do it yourself anyway! See you next time. **NV**

IT'S SPRINGTIME AT RAMSEY!

Four-Mode Keyless Entry Test Set

NEW!

- ✔ Troubleshoot vehicular keyless entry and wireless remote control systems!
- ✔ Detects and verifies key fob to vehicle signals as well as vehicle to key fob signals!
- ✔ Separate visual indicators for the presence of 315/433MHz, 125kHz, 20kHz and IR signals!
- ✔ Can also test virtually any wireless IR/RF control and building access systems!
- ✔ Can even test household and home entertainment IR remote controls for the presence of IR signal output!

Ahh!!... the conveniences of today's technology in our modern world! Voice recognition, LED's instead of incandescent bulbs, on-board computers, on-board hard drives, automatic parallel parking, automatic radar cruise control, and of course, wireless remote controls! They make it so simple, just have the "key" (called a key fob) somewhere in your pocket or purse, get near the vehicle, it knows that you are there! Touch the door handle and the vehicle unlocks. Get in and touch the start button and the vehicle starts. You have yet to use a key through the whole process! And don't forget all the wireless controls for your house lights, building access and entertainment systems. They're so great… until they don't work!

Just like the days of "plugs, points, and condenser" are over, so are the days of having the hardware store grind out a spare key for your car! Now when your keyless access system doesn't work, you need to accurately detect what part of the system is malfunctioning. This could be anything from a dead battery in the key fob, a "brain-dead" key fob, to malfunctioning sensors, antennas, or other system components in the vehicle. The WCT3 is designed for both the car dealer service shops as well as the consumer. Until now there was no way to determine where the system was failing. Please note that the WCT3 simply verifies the generation of the control signals. Indication of signal presence is not an indication the encoded data is valid, nor is it a reader of that code, so don't worry, this will not help anyone steal your car!

First, let's cover a few basics about vehicular keyless entry. In general, (not all systems are created equal), the vehicle itself generates a signal at 125 kHz or 20kHz. This is the signal that is used to "talk" to your individual key fob. Upon receiving the signal, your key fob "returns" a 315MHz signal uniquely encoded with an identification code and unlock command. If the embedded codes of the vehicle and your key fob match, you're in! Once you have "unlocked" the vehicle, and are inside the vehicle, the presence of your key fob is detected in the same way when the "start" button is pressed. If the codes match, the vehicle can be started. Some manufacturers also use Infrared (IR) signals in their key fobs to add additional user control functions to the vehicle. In that case, the key fob generates a modulated IR signal that is received by the vehicle's IR detectors placed throughout the perimeter of the vehicle.

Testing your system is easy. To test the complete 125 kHz/315 MHz communications path just stand close to the vehicle with the WCT3 and your key fob in hand. Press the test button and the WCT3 will detect and display the presence of the vehicle's 125kHz/20KHz signal and, if they "handshake", will also detect and display the presence of your key fob's 315MHz return signal. You can independently test key fob only signals (panic, lock, trunk, etc.) by holding the key fob near the WCT3, pressing the test button, and pushing the function button on the key fob. The same functionality testing can be done with IR key fobs. The modulated IR signal is detected and will illuminate the IR test LED on the test set. If you know a few "secrets" you can also see if the tire pressure sensors/transmitters are generating signals or the built-in garage door opener in your rear view mirror is transmitting a signal! But the WCT3's uses go beyond the automotive world. The majority of building wireless access systems also utilize 125 kHz. Just hold the test set near the building access sensor and the WCT3 will detect the 125 kHz signal. That will help you troubleshoot door access locations that are not working. It gets even better... you can use the WCT3 to test virtually any other 315 MHz, 433 MHz, 125kHz, 20kHz and IR wireless control system to verify generation of a signal. We should rename this "the handy-dandy, universal, wireless remote control tester"!

The WCT3 test set is housed in a compact 2.25" x 4.6" x 9" case and is powered by a standard 9VDC battery. The test set is available as a do-it-yourself hobby kit or factory assembled and tested. For the kit builder, the WCT3 contains both SMT and through-hole components, with 170 solder points. If you're a car dealer, independent service shop, or simply an owner of a newer vehicle with keyless entry, or have wireless entertainment controls you can't afford not to have a WCT3!

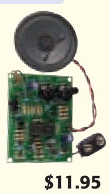
WCT3	**Four-Mode Keyless Entry Test Set Kit**	**$59.95**
WCT3WT	**Four-Mode Keyless Entry Test Set, Factory Assembled & Tested**	**$99.95**

Digital Voice Changer

This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! You can sound just like a robot, you can even ad vibrato to your voice! 1.5W speaker output plus a line level output! Runs on a standard 9V battery.

MK171 Voice Changer Kit $14.95

Steam Engine & Whistle



Simulates the sound of a vintage steam engine locomotive and whistle! Also provides variable "engine speed" as well as volume, and at the touch of a button the steam whistle blows! Includes speaker. Runs on a standard 9V battery.

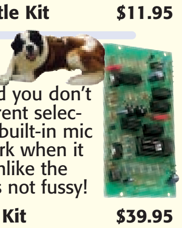
MK134 Steam Engine & Whistle Kit $11.95

Laser Trip Senser Alarm

True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1 Laser Trip Sensor Alarm Kit $29.95

Electronic Watch Dog



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

K2655 Electronic Watch Dog Kit $39.95

The Learning Center!

Beginners To Advanced... *It's Fun!*

- ✔ Learn and build!
- ✔ 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.

PL200 Includes 200 very creative fun projects and includes a neat interactive front panel with 2 controls, speaker, LED display and a meter.

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.

PL130A	**130-In-One Lab Kit**	**$39.95**
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**

ramsey
www.ramseykits.com

Look for the QR tag like this throughout our catalog and print ads. Use the Tag app in your smart phone to automatically get more information for that specific product, or in this case, it will take you right to ***www.ramseykits.com!***

- ✔ ***Build It!***
- ✔ ***Learn It!***
- ✔ ***Achieve It!***
- ✔ ***Enjoy It!***

Follow Us and SAVE $$

Follow us on your favorite network site and look for a lot of super deals posted frequently... exclusively for our followers!

Digital Controlled FM Stereo Transmitter

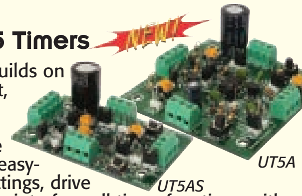
- ✔ PLL synthesized for drift free operation
- ✔ Front panel digital control and display of all set tings and parameters!
- ✔ Professional metal case for noise-free operation
- ✔ EMI filtering on audio and power inputs
- ✔ Super audio quality, rivals commercial broadcasts
- ✔ Available in domestic kit or factory assembled export versions

For nearly a decade we've been the leader in hobbyist FM radio transmitters. We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters! The FM30 is designed using through-hole technology and components and is available only as a do-it-yourself kit with a 25mW output very similar to our FM25 series. Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35WT version with 1W output for our export only market!

All settings can be changed without taking the cover off! Enter the setup mode from the front panel and step through the menu to make all of your adjustments. A two line LCD display shows you all the settings! In addition to the LCD display, a front panel LED indicates PLL lock so you know you are transmitting. Besides frequency selection, front panel control and display gives you 256 steps of audio volume (left and right combined) as well as RF output power. A separate balance setting compensates for left/right differences in audio level. In addition to settings, the LCD display shows you "Quality of Signal" to help you set your levels for optimum sound quality. And of course, all settings are stored in non-volatile memory for future use! Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC plug-in power supply. The stylish black metal case measures 5.55"W x 6.45"D x 1.5"H. Call for FM35BWT export information. *(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)*

FM30B Digital Controlled FM Stereo Transmitter Kit, 0-25mW, Black $199.95

Ultimate 555 Timers NEW!



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

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

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

OBDII *CarChip Pro*

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

8226 CarChip Pro OBDII Monitor-Asmb $79.00

RF Preamplifier

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

SA7 RF Preamp Kit $19.95

Touch Switch

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

TS1 Touch Switch Kit $9.95

Doppler Direction Finder

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

DDF1 Doppler Direction Finder Kit $169.95

Mad Blaster Warble Alarm

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

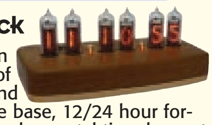
MB1 Mad Blaster Warble Alarm Kit $9.95

Laser Light Show

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

LLS1 Laser Light Show Kit $49.95

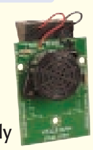
Retro Nixie Tube Clock



Genuine Nixie tubes popular in the 50's brought back in one of the neatest digital clocks around today! Hand made teak maple base, 12/24 hour format, soft fade-out, auto-dim, and a crystal time base at 20ppm! Tube kits also available.

IN14TM Teak Maple Nixie Clock Kit $329.95

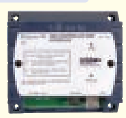
Water Sensor Alarm



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

MK108 Water Sensor Alarm Kit $6.95

USB DMX Interface



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

K8062 USB DMX Interface Controller Kit $67.95

HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

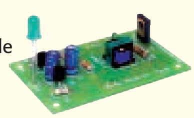
PG13 HV Plasma Generator Kit $64.95

Air Blasting Ion Generator

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

IG7 Ion Generator Kit $64.95

Tickle-Stick Shocker



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

TS4 Tickle Stick Kit $12.95

Speedy Speed Radar Gun

Our famous *Speedy* radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. You supply two coffee cans! Runs on 12VDC or our AC125 supply.

SG7 Speed Radar Gun Kit $69.95

Tri-Field Meter Kit

THE GHOST DETECTOR!

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

TFM3C Tri-Field Meter Kit $74.95

Passive Aircraft Monitor

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

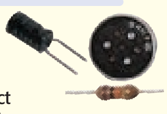
ABM1 Passive Aircraft Receiver Kit $89.95

Broadband RF Preamp

Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.

PR2 Broadband RF Preamp $69.95

Electret Condenser Mic



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

MC1 Mini Electret Condenser Mic Kit $3.95

Sniff-It RF Detector Probe

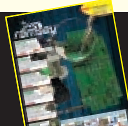
Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!

RF1 Sniff-It RF Detector Probe Kit $27.95

3-In-1 Multifunction Lab

The handiest item for your bench! Includes a RoHS compliant temp controlled soldering station, digital multimeter, and a regulated lab power supply! All in one small unit for your bench! It can't be beat!

LAB1U 3-In1 Multifunction Solder Lab $134.95



Get the latest 2011 Ramsey Hobby Catalog today! Filled with some of the neatest goodies around! Order yours today... Or be green and download the PDF at *www.ramseykits.com/catalog!*

800-446-2295

www.ramseykits.com

RAMSEY ELECTRONICS, LLC
590 Fishers Station Drive
Victor, NY 14564
(800) 446-2295
(585) 924-4560

Q&A

WHAT'S UP:

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

- ✔ Battery Charge Limiter
- ✔ 433 MHz Transmitter
- ✔ SPICE Modeling

■ 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**

BATTERY CHARGE LIMITER

Q I have converted a 1975 VW Beetle to electric and use nine deep cycle lead acid batteries in series. My problem is, when I charge the batteries, they do not charge equally. I would like a circuit to connect across each 12 volt battery which will limit the voltage to 14.5 volts while the weaker batteries are coming up. This requires a circuit that will bypass up to three amps when the voltage is 14.5 volts. Thanks for any help you can give me on this.

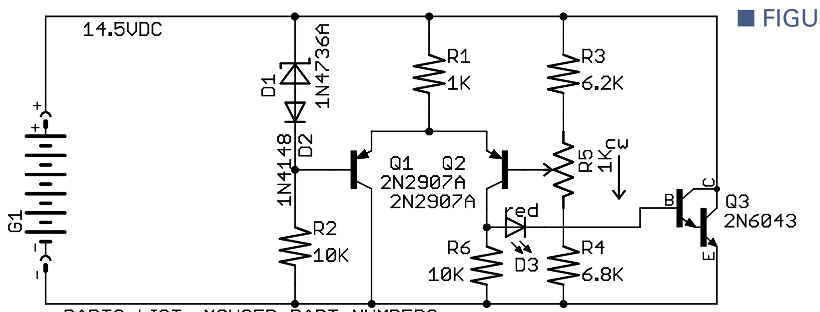
— Don Bohn

A The schematic of **Figure 1** should do the job. I tried to come up with the simplest and cheapest design; that is why the schematic shows 2N2907A but the parts list is 2SA733P. The 2N2907A is hermetically sealed and nearly ten times the price of the plastic equivalent. Of course, the hermetic unit is more reliable; you pay the money and take your choice.

The diode in series with the 6.2 volt zener is for temperature compensation. You can buy a temperature compensated 6.8 volt zener but it is more expensive than doing it yourself, and this is less expensive than a TL431 or LM4040 voltage reference. The range of the trimpot (R5) is about 13.5 to 15 volts. To do the adjustment, connect the circuit in series with the charger (no battery). The LED in series with the power transistor base lights when the circuit is shunting to alert you that the battery is fully charged.

At three amps, the power transistor (Q3) will be dissipating nearly 50 watts, so a good heatsink is needed. I think a sheet of 1/8 inch aluminum 18 x 18 inches will work, or you can buy a 1°C per watt heatsink for $55.19; Mouser part #558-HS103.

Don tells me that the converted VW will go 35 miles on a charge and can get up to 65 MPH, but he has to shift down to second gear on hills. It uses a Curtis PWM controller rated 400 amps and 120 volts.



■ FIGURE 1

PARTS LIST, MOUSER PART NUMBERS

D1	6.2V ZENER, DO-41	78-1N4736A	$0.04 ea
D2	SMALL SIGNAL DIODE, DO-35	771-1N4148,143	0.02
D3	RED LED, T1 3/4	638-333-2SDRDS5304	0.15
Q1, Q2	PNP, 60V, 500mA	512-2SA733P	0.09
Q3	NPN DARLINGTON, 8A RATED	863-2N6043G	0.86
R5	MULTITURN POT, 1/4W, 1K	81-PV37W102C01B00	1.25
ALL OTHER RESISTORS 1/4W, 5%		291-VALUE-RC	0.04/10

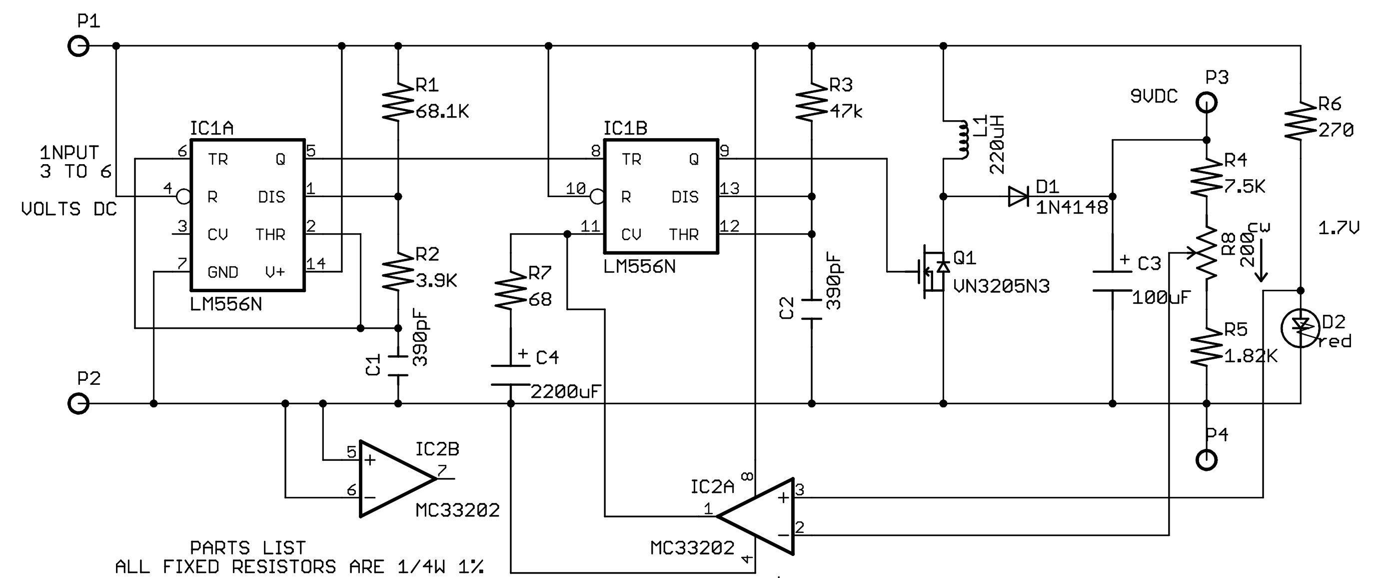
STEP-UP MODULE

Q I bought a hand-crank Dynamo (from **Jaycar.com**; #MD7000), and would like to build a step-up module in order to generate at least 9 VDC at 35 mA with ease. The dynamo produces three volts at 10 mA at a comfortable cranking speed. Can you please help me with such a schematic — I prefer all the parts from a single source such as Mouser.

After getting your feedback, I found another hand-crank generator which produces 6.3 volts at 200 mA max. I'd like a step-up module with an output for 9 VDC at 35-45 mA from whatever comes from the generator, without having to break the plastic handle.

— Michael Williams

A Your first find is not possible. The power you need is .035*9 = 315 milliwatts but the power output of the dynamo is .01*3 = 30



PARTS LIST

ALL FIXED RESISTORS ARE 1/4W 1%

IC1	556 DUAL TIMER CMOS	511-TS556CN	$0.99
IC2	DUAL R/R OPAMP	863-MC33202PG	1.23
C1, C2	390pF CERAMIC, NPO	81-RPE5C1H391J2P1A03	0.22
C3	100uF 16V ALUMINIUM	140-RXJ101M1CBK0611P	0.44
C4	2200uF, 6.3V, ALUMINIUM	647-UVZ0J222MPD	0.48
Q1	NMOS LOGIC LEVEL 1.2A 50V	689-VN3205N3-G	0.89
L1	220uH 1AMP	542-2100HT-221H-RC	2.61
D1	GP DIODE, 1N914 OR 1N4148	771-1N4148,143	0.02
D2	RED LED, T1 3/4	696-SSL-LX20465ID	0.15
R8	200 OHM TRIMPOT	81-PV37W201C01B00	1.25

■ FIGURE 2

milliwatts. You may be able to find a 24 VDC motor on eBay that will fit in place of the one supplied. I expect you would need to spin a 24 volt motor at 3,000 RPM to get 9 VDC output.

Your second find has a power output of 1.2 watts and will do the job easily. I designed a DC/DC converter that operates from three volts so you won't have to crank so hard. In **Figure 2**, IC1A is an astable timer generating a frequency of 50 kHz. IC1B is a one-shot that is triggered by IC1A and pulse width controlled by feedback through IC2. This is a flyback boost circuit; when Q1 turns off, the charge built up in L1 is dumped into C3. D2 is a red LED which has an "on" voltage of 1.75 volts and is used as a voltage reference. When the output voltage is too high, the output of IC2 is reduced which makes the pulse width less, which lowers the voltage. The function of R7 and C4 is to stabilize the loop and prevent it from being too noisy.

Q1 has a worst case turn-on voltage of 2.4 volts and will probably not work. The typical VN3205N3 works great, however. I breadboarded the circuit and measured the efficiency to be 71%. I didn't buy the inductor; I wound 27 turns of #22 hookup wire on a RadioShack core (#273-104).

433 MHz TRANSMITTER

Q I built this 433 MHz wireless receiver from Chaney Electronics (kit #C6847 ... by now, it may be discontinued) and would like to build a powerful transmitter for it.

I do have some requirements for this transmitter: NO tuned air-core coils, easy to build, powered from a 9V battery, transmit at least to 70 meters, and parts available from Mouser.

I did experiment with some transmitters sold by **Goldmine-elec.com** (Quorum Sensor AS-103) with not so great results, so that's why I'd like to build my own transmitter. Can you please help with a simple to build schematic?

— Don Franklin

A 433 MHz is above my comfort zone; 300 MHz is about my limit. It appears that you are looking for a design using resonant transmission line or printed inductors. I have not done any of that. I did build a 433 MHz transmitter/receiver using parts from Qkits and a ceramic antenna from Mouser. I got a 1,000 foot range using a parabolic reflector. Unfortunately, neither Mouser nor Qkits are listing those parts now. I did find a transmitter on eBay for $20 from China, shipping included. The power output is 400 mW which should be plenty for your application. The eBay URL is: **http://cgi.ebay.com/3000M-400mW-RF-Wireless-Transmitter-Module-433Mhz-/250691048701?pt=LH_DefaultDomain_0&hash=item3a5e59d4fd#ht_3810wt_914**.

SPICE MODELING

I didn't get a lot of questions this month, so I am going to describe how to make a subcircuit model in SPICE. First, a short tutorial on SPICE:

SPICE is just a text file; the first line has no symbol requirements and is the title. Every other line must start with a symbol that SPICE recognizes and must be in the format required

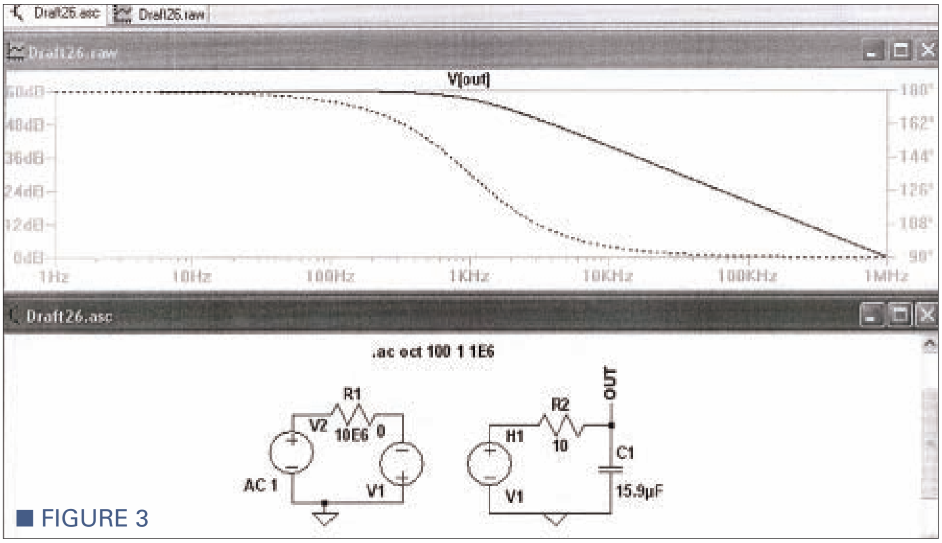


FIGURE 3

```
.SUBCKT OPAMP 1 4 5
*INPUT OUTPUT GND
R1 2 1 10E6
V1 5 2 0
H1 3 5 V1 1E10
R2 4 3 10
C1 4 5 15.9E-6
.ENDS OPAMP
```

FIGURE 4

by that symbol. The last line is .END. There is much more to SPICE than I will describe here; the reader is encouraged to get a book on SPICE. I am using *Simulating With Spice* by Meares and Hymowitz; published by Intusoft.

The SPICE circuit is described by node numbers to which the parts are connected; for example: SYMBOL NODE1 NODE2 NODE3 ... VALUE. Node1, node2, etc., are the numbers of the connection nodes; VALUE is a parameter of the device.

R1 5 8 10E3	Resistor
C16 8 0 .01E-6	Capacitor
LP 1 2 .001	Inductor
V+ 1 0 5	Voltage source
I1 1 0 .5	Current source

For active components such as diodes and transistors, there must be a .MODEL control statement in the file which describes the device. The control statement is best obtained from the manufacturer.

Some of the symbols and their format are:

- Any line starting with an asterisk is ignored (comment line).
- Dname anode cathode modelname: diode.
- Qname collector base emitter modelname: bipolar transistor.
- Mname drain gate source modelname: MOSFET.
- Jname drain gate source modelname: junction field effect transistor (JFET).
- Xname N1 N2 N3 ... Subname: subcircuit call; there must be a .SUBCKT control statement in the file which describes the sub-circuit. What I am describing here is a sub-circuit model which can have a .SUBCKT call within it but cannot call itself as a subcircuit.
- Fname +node –node V1 value: current controlled current source; you will have to put a zero voltage source in the circuit to measure the current. The current of the (current) source flows externally from positive to negative provided the voltage source is oriented such that the current flows internally from negative to positive. For advanced users, there is a poly parameter which allows multi-dimensional control, but I am not going into that. Value is the multiplication factor for input/output.
- Hname +node –node V1 value: current controlled voltage source; same description as F device.
- Gname +node –node nc1 nc2 value: voltage controlled current source; the current flows externally from +node to –node, provided nc1 is the positive controlling node and nc2 is the negative controlling node. You can reverse either one to reverse the current.
- Ename +node –node nc1 nc2 value: voltage controlled voltage source; nc1 and nc2 are the

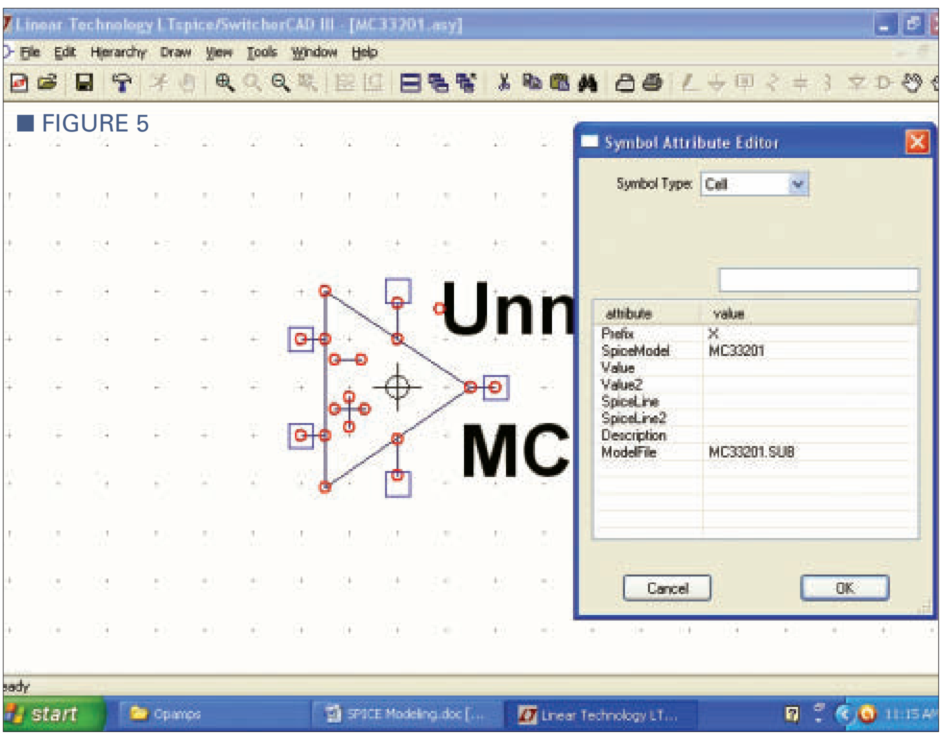


FIGURE 5

positive and negative controlling nodes, respectively.

Your sub-circuit file will have the form: .SUBCKT subname n1 n2 n3 — up to 20 nodes can be used. The nodes n1, n2, etc., are internal nodes of the sub-circuit which are to be external connections. The nodes can be in any order, but the nodes of the X call must be in the same order. Normally, you will have a comment line that explains the order of the connections. The numbers used in the X call do not have to be the same as the .SUBCKT numbers; only the order is important.

The sub-circuit model should be the simplest one that will give usable results. For example, to model an op-amp having a gain of 60 dB and 1 MHz bandwidth with 10 ohms output impedance, the circuit of **Figure 3** will work. R1 is the input impedance; one volt at the input gives 0.1 microamp current and a multiplier of 1e7 is needed to get up to one, then 1e3 is needed to get 1,000 (60 dB), so the multiplier for H1 is 1e10. Note that V1 has the + side ground. That makes the op-amp inverting. You should also be aware that SPICE requires a ground to run but it is not a good idea to have ground (node 0) in the sub-circuit. That is why I made ground node 5 in the sub-circuit. See the sub-circuit listing in **Figure 4**. You can calculate the value of C1 for 1 MHz bandwidth, but I did it by trial and error.

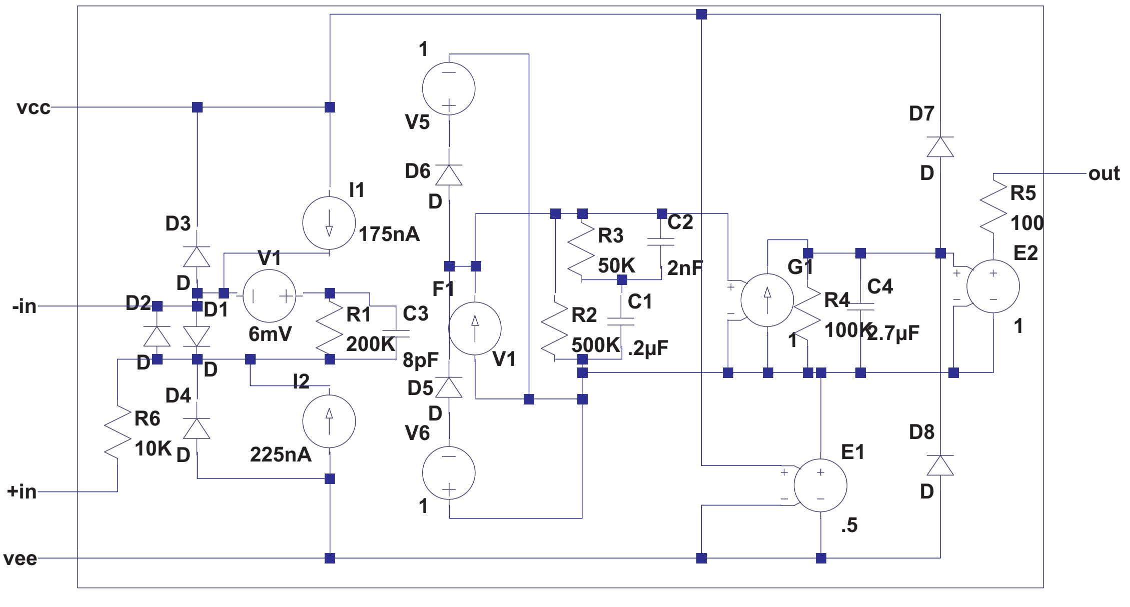
I wanted a model of the op-amp MC33201 which is rail-to-rail input and output, so I downloaded the file from ON Semiconductor. The file was a complete SPICE description of a unity gain amp with ±1.5 volt supplies, so I used copy and paste to extract just the sub-circuit. I used drag and drop to move the sub-circuit file to the LTC sub-circuit directory and copied an op-amp symbol, editing the attributes to MC33201. Note that in the last attribute (ModelFile), you should put a sub-circuit file name or else you will get an error message (see **Figure 5**).

The model didn't work right away, and it took me a while to figure out that the nodes were not in the standard LTC order, which is: +in, - in, +V, -V, out. The downloaded sub-circuit didn't have the order of nodes identified, but I figured out that it was: -in, +in, out, +V, -V. The model ran okay after I put the nodes in the order required by the LTC symbol, except that the output is distorted if you run it with ±1 volt supplies.

I tried to make a model that would work without distortion using ±1 volt supplies with limited success. My model does the rail-to-rail input okay but the output can

LOW VOLTAGE MC33201 MODEL

■ FIGURE 6



exceed the rails. I tried to use transistors to simulate the output clamping at the rail, but the simulation time is so long it isn't worthwhile. My model also doesn't work properly in the frequency domain. An .AC analysis will show unlimited bandwidth but the gain is correct.

Figure 6 is the Switcher CAD circuit of the model. V1 simulates the input offset and also is the current measure for the next stage.

F1 is a current-controlled current source controlled by V1. It is the gain stage and is voltage limited in order to have slew rate limiting in the next stage (which is a voltage controlled current source). The charging and discharging of C4 provides the slew rate limit.

E2 is a voltage-controlled voltage source which allows the output resistance to be 100 ohms via R5.

E1 is a voltage source controlled by VCC and VEE and has a value of 1/2. This avoids having ground in the model which may not be necessary in this case, but looks better to me.

Years ago, I wrote a Basic program that would generate an op-amp model from the datasheet parameters. I tried that as a comparison; the model worked okay in both transient and AC analysis modes but doesn't work below a ±1.5 volts power supply and is not rail-to-rail.

I designed a two-stage bandpass filter at 15 kHz and used the ON Semiconductor model, but the AC analysis failed due to exceeding the iteration limit. Exceeding the iteration limit is a common problem in non-linear transient analysis but AC analysis is supposedly linear, and I never before had an AC analysis fail for that reason. I changed the model to the low voltage one and it ran okay with perfect theoretical response. I then tried the op-amp model that was made with the Basic program and it ran okay, but the filter response was shifted to a lower frequency. I suspect the frequency shift is due to phase shift in the op-amp and is more like the actual device. The three models all work differently and are useful as long as their limitations are recognized. **NV**

MAILBAG

Dear Russell: Re: Low Battery Circuit, January '11, page 24.

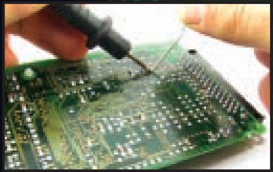
Is there an error in the vbias equation of Figure 4 on page 24 of the January '11 issue?

Figure 4 gives the equation for Vbias as: V bias = (Vout*Vswhi - Vouthi*Vswlo)/(Voutlo - Vswlo - Vouthi*Vswhi) = (0*2 - (10*1.83))/(0 - 1.83 - (10 * 2) = -18.3/-21.83 = 0.838V.

The article gives the result as 1.86V.

— **Marc Forgey**

*Response: You are right. There is a typo in the equation (my error). The correct equation is: Vbias = (Vout*Vswhi – Vouthi*Vswlo)/(Voutlo – Vswlo – Vouthi + Vswhi)*



Test & Measurement Kits for Electronic Enthusiasts

KIT OF THE MONTH

Transistor Tester

KA-1119 $17.50 plus postage & packing

Have you ever unsoldered a suspect transistor only to find that it checks OK? Troubleshooting exercises are often hindered by this type of false alarm. You can avoid these hassles with the In-Circuit Transistor, SCR and Diode Tester. The kit does just that, test drives without the need to unsolder them from the circuit! Kit includes a jiffy box, battery, electronic components and a panel showing truth table for device checking.

CONSISTENT SELLER FOR OVER 25 YEARS!

CAR BATTERY MONITOR

KA-1683 $13.00 plus postage & packing

Don't get caught with a flat battery! This simple electronic voltmeter lets you monitor the condition of your car's battery so you can act before getting stranded. 10 LEDs tell you your battery's condition.

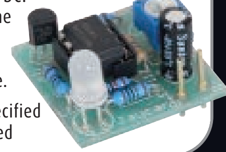
- Kit includes PC board and all components
- PCB Dimensions: 62 x 39mm

LED BATTERY VOLTAGE INDICATOR

KA-1778 $6.25 plus postage & packing

This tiny circuit measures just 25mm x 25mm and will provide power indication and low voltage indication using a bi-colour LED. The LED will be green when above the set point & red when below. The set point is adjustable using a trim-pot. The circuit is suitable for equipment powered from 6-30VDC. With a simple circuit change, the bi-colour LED will produce a red glow to indicate that the voltage has exceeded the value.

- PCB, bi-colour LED and all specified electronic components supplied



DIGITAL MULTIMETER KIT

KG-9250 $15.75 plus postage & packing

Learn everything there is to know about component recognition and basic electronics with this comprehensive kit. From test leads to solder, everything you need for the construction of this meter is included.

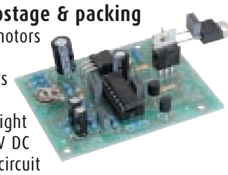
- Dimensions: 67(W) x 123(H) x 25(D)mm

10A DC MOTOR SPEED CONTROLLER

KC-5225 $18.00 plus postage & packing

Ideal for controlling 12VDC motors in cars such as fuel injection pumps, water/air intercoolers and water injection systems. You can also use it for headlight dimming and for running 12V DC motors in 24V vehicles. The circuit incorporates a soft start feature to reduce inrush currents, especially on 12V incandescent lamps. Includes PCB and all electronic components to build 10A version.

- PCB Dimensions: 69 x 51mm
- Output can increase to 20A with extra MOSFET available separately ZT-2450 $6.25

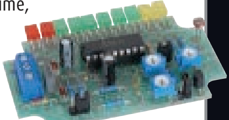


VOLTAGE MONITOR KIT

KC-5424 $14.50 plus postage & packing

This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your car. The kit features 10 LEDs that illuminate in response to the measured voltage, preset 9-16V, 0.-5V or 0-1V ranges, complete with a fast response time, high input impedance and auto dimming for night time driving.

- Kit includes PCB with overlay, LED bar graph and all electronic components.
- 12VDC
- Recommended box: UB5 use HB-6015 $2.00

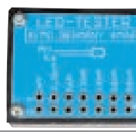


LED TESTER MODULE

AA-0272 $11.25 plus postage & packing

With this basic but essential tool it is possible to check the function, brightness, colour and polarity of all kinds of light emitting diodes (LED). The LED to be tested plugs into the front panel, at the current you wish to test it with. Two 10 mA positions have been included on this multi-LED tester so that comparisons between two LEDs can be made simultaneously.

- Requires 9V Bolt (not included)
- Test currents: 1mA, 2.5mA, 5mA, 10mA, 20mA, 50mA
- Dimensions: 58 x 44 x 25mm



SLA BATTERY HEALTH CHECKER KIT

KC-5482 $57.75 plus postage & packing

The first versions of the battery zapper included a checker circuit. The Mk III battery zapper (KC-5479) has a separate checker circuit - and this is it. It checks the health of SLA batteries prior to charging or zapping with a simple LED condition indication of fair, poor, good etc.

- Overlay PCB and electronic components
- Case with machined and silk-screened front panel
- PCB Dimensions: 185 x 101mm

Don't just sit there BUILD SOMETHING!

SFX KITS

Theremin Synthesiser Kit MKII

KC-5475 $54.00 plus postage & packing

The ever-popular Theremin is better than ever. It's easier to set up with extra test points for volume adjustment and power supply measurement and it now runs on AC to avoid the interference switchmode plugpacks can cause. It's also easier to build with PCB-mounted switches and pots to reduce wiring to just the hand plate, speaker and antenna. It also has the addition of a skew control to vary the audio tone from distorted to clean.

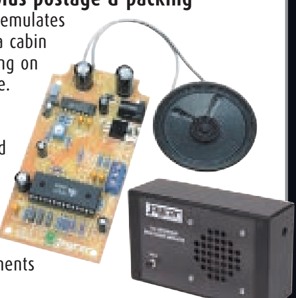
- Complete kit contains PCB with overlay, pre-machined case and all specified components

Starship Enterprise Door Sound Emulator

KC-5423 $25.00 plus postage & packing

This easy to build kit emulates the unique sound of a cabin door opening or closing on the Starship Enterprise. The sound can be triggered by switch contacts or even fitted to automatic doors.

- Kit supplied with PCB with overlay, speaker, case and all specified components
- 9-12VDC regulated



LOW CAPACITANCE ADAPTOR FOR DMM KIT

KC-5493 $22.00 plus postage & packing

Many modern multimeters come with capacitance ranges, but they're no good for very small values. This kit is a nifty little adaptor that allows a standard digital multimeter to measure very low values of capacitance from less than one picofarad to over 10nF. It will allow you to measure tiny capacitors or stray capacitances in switches, connectors and wiring. The kit is complete with PCB, components and case. All you'll need is a 9V battery and just about any modern DMM.

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 30/4/2011

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)
Note: 10-14 days for air parcel delivery

Order online: www.jaycar.com

Jaycar Electronics

MID-RANGE OSCILLOSCOPE PLATFORM

LeCroy Corporation announces the launch of WaveRunner 6 Zi — its newest mid-range oscilloscope series. The new platform is the latest design in a comprehensive rollout of technology-leading products that LeCroy initiated in the fall of 2010.

The new flagship WaveRunner features 4 GHz bandwidth and 40 GS/s per channel sample rates with an innovative new industrial design, comprehensive serial-data, and probing solutions.

The WaveRunner 6 Zi oscilloscopes feature a pristine signal path that offers unmatched signal fidelity with low electronic noise. In addition, LeCroy has designed the WaveRunner 6 Zi with an industry-first pivoting display that permits viewing signals vertically as well as horizontally to obtain more detail for optimum analysis. The comprehensive toolset includes everything engineers need to productively validate and thoroughly debug designs.

For more information, contact:
LeCroy Corporation
Web: **www.lecroy.com**

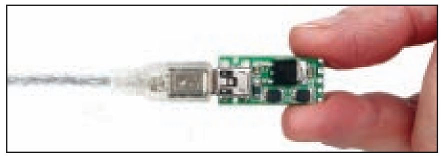
DURABLE SKINS NOW AVAILABLE IN BLACK

Linx Technologies now offers its durable, rubberized OEM transmitter skins in black. The skins minimize the risk of damage and give OEM transmitters a distinctive look. They provide enhanced protection from scratches, bumps, and minor falls for any Linx OEM compact or long-range handheld transmitter.

The rugged skin is a perfect way to protect transmitters in challenging consumer and industrial environments. Custom colors are available for high volume orders.

For more information, contact:
Linx Technologies
159 Ort Lane
Merlin, OR 97532
Web:
www.linxtechnologies.com

NEW VERSATILE TOOLS AND BOARDS



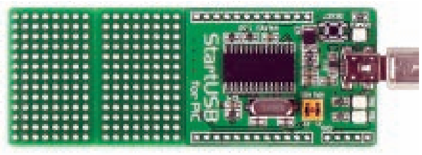
USB REG Board

If you've ever wanted to just get power from a USB port without the need for communication ability, the new USB-REG board from MikroElektronika can help you do this. The board features a MC33269DT power regulator circuit for creating 3.3V, but you can also get 5V directly from the USB. The board is compact and can be used either for powering a prototype or it can be integrated as a powering solution in a final product.

Solar Panel Board

These new solar panel boards offer a new solution for an alternative power supply. The solar boards offer a simple, yet very effective way to get your device working under conditions where an ordinary power supply isn't available. You can build robots, autonomous vehicles, solar chargers, and all sorts of mobile devices.

The solar panels are made of quality materials and are easily connected together to form a larger panel, in order produce more power.



Start USB for PICs

MikroElektronkia also introduces a new versatile development board — the Start USB for PIC. It features a PIC18F2550 with fast USB 2.0 support and can easily become a complete device. It has great connectivity potential, so it can add USB communication to a prototype, or can itself become a USB MP3 player, USB datalogger, or USB Flash stick. Place additional components on two available prototyping areas, and you have a final product.

For more information, contact:
MikroElektronika
Web: **www.mikroe.com**

NEW PROTOMAT S-SERIES

LPKF Laser & Electronics is continuing its innovative efforts in circuit board prototyping with the redesign of their best known product group: the ProtoMat® S-Series. Each system features improved functions, a higher level of automation, and upgrade options.

The entry-level ProtoMat S43 is a milling machine that provides a great introduction into the world of professional rapid PCB prototyping. For those with an occasional use and/or limited budget, the ProtoMat S43 has the precision and capacity for drilling, de-paneling, and structuring printed circuit boards and engraving front panels.

It comes equipped with a 40,000 RPM spindle motor, a working area of 9″ x 12″, and has the ability to produce multiple design iterations in the same day. The state-of-the-art LPKF ProtoMat S63 circuit board plotter masters 2.5D material processing such as the routing of pockets, and features a programmable spindle speed of up to 60,000 RPM, making it ideal for drilling test adapters or housing enclosures.

Entirely new to the system is a mounted dispenser which applies soldering paste to the circuit board automatically with minimum data preparation, and standard to the system is an intelligent fiducial camera, a 15-position automatic tool change, and an automatic milling width adjustment. This lets nothing stand in the way of producing precise double-sided and multilayer circuit boards right in the electronics lab.

For more information, contact:
LPKF Laser & Electronics
Web: **www.lpkfusa.com**

SHOWCASE

BUILDING THE STROBOSCOPIC ZOETROPE

By Walter Noon

It's always exciting when something that's very old is new again! In the case of the Zoetrope, we can journey all the way back to 180 AD. There, inventor Ding Haun of China, invented a spinning wheel driven by convection which "made fantasies appear" with a series of painted panels arranged to create a short animation.

The wonderful appeal of the Zoetrope has been rediscovered time and again throughout history, and is once again being rediscovered with a new modern electronic "spin."

FIGURE 1.

On a recent trip to California Adventure in Anaheim, CA, I was amazed to find a beautiful zoetrope produced by Pixar was one of the most popular exhibits at the park! There among *multimillion dollar attractions*, one of the oldest technologies was what everyone was most excited to see and talk about.

Building your own "stroboscopic" zoetrope is a particularly entertaining project because it combines simple mechanics with electronics. It's simple enough, in fact, to make an excellent evening project.

With your zoetrope, you will be able to quickly create truly amazing live animations of both two dimensional and even *three dimensional* objects. The possibilities for what you can do with your zoetrope are as unlimited as the art of animation itself. Trust me, coming up with a story to tell in just a few frames can make you feel a little "Zen."

You do not have to be a great artist to create great zoetrope animations. Posable toys, drawings, and even ready-made flipbook animations can be used with your zoetrope.

I do want to warn you ahead of time that once your zoetrope is running, you will find that the fun of creating animations for it is both time-consuming and addictive!

Zoetrope Basics

A classic zoetrope works because of persistence of vision. In viewing an object, the human eye will experience an after-image of approximately 1/25 of a second. By arranging a series of drawings or objects on a rotating plate or cylinder and viewing those objects one at a time in rapid succession, you can create a very strong illusion of contiguous motion.

Early zoetropes used a series of slits in a rotating outer cylinder (see **Figure 1**) to allow viewing of one image in the same position at a time. By having a sequence of images — each slightly different in position — it's possible to create a realistic animation.

In our modern stroboscopic zoetrope, we'll use a flashing strobe light to visually "freeze" the motion of a large rotating disk, and bring our character's motions mysteriously to life. In order to "sync" our strobe perfectly to the action, we'll mount some neodymium magnets at each segment on the disk where we would like a flash, and then trigger our strobe with a simple reed switch. In addition, we'll discuss adding a circuit for precision strobe control of our animation later.

The rotating disk for this article has been divided into exactly 16 equal sections (see **Figure 2**), however, any number of sections is possible. By mounting 16 objects (2D or 3D) — one on each of these sections — and positioning each of those objects slightly differently, they will literally seem to come to life when viewed in a darkened room spinning under a sequenced strobe light. The effect of seeing 3D objects spring to life when the strobe begins to fire really has to be seen to be appreciated.

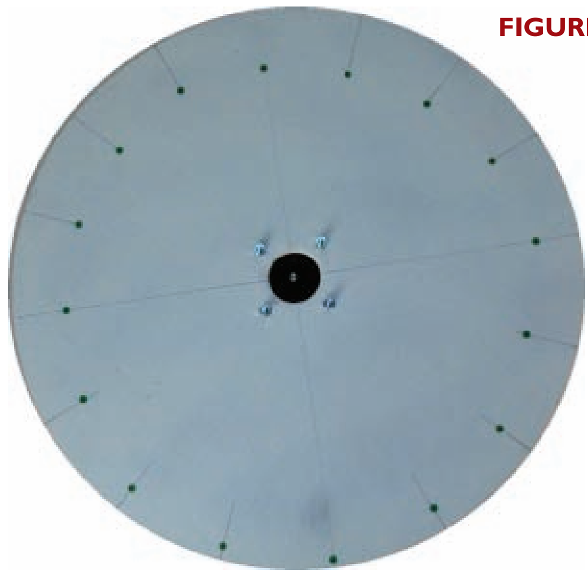


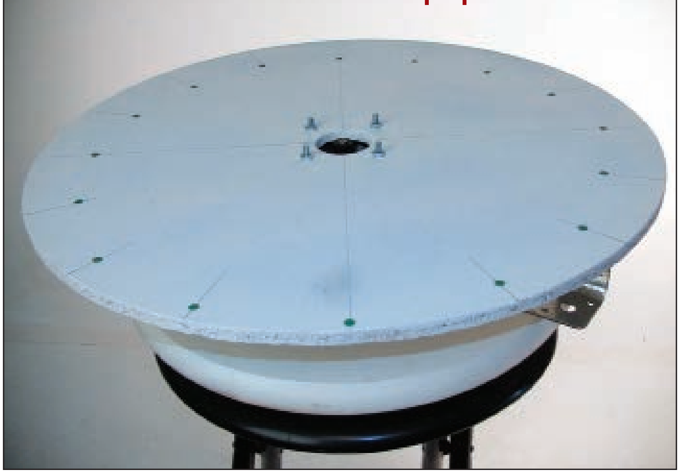
FIGURE 2.

Making Your Wheel

Mechanically, all that is needed is a basic turntable of any kind. The speed of the turntable (RPM) will determine the length of your animation, and the number of sections you segment your wheel into will determine the number of "frames" in your animation. The more frames you have and the higher rate at which they are displayed, the smoother your animation will appear.

Typical commercial "frame rates" for animation would be 24 frames per second for movies and 30 frames per second for video. However, you can still have an attractive and reasonably smooth animation at as little as 12 frames per second (possibly less). Once again, you can make your wheel any size and any number of frames. My particular wheel worked great with 16 frames.

View of the entire zoetrope platform.



Begin by finding a ready-made disk or cutting one from any material (I used 1/4 particle board). My particular disk was 19" in diameter to accommodate a 2.5" plastic shark I wanted to animate initially.

In order to get 16 equal segments, I simply drew a line exactly bisecting the wheel, and then drew a line perpendicular to the first line, bisecting it (creating four equal spaces). Check out **Figure 3**. Continue bisecting the

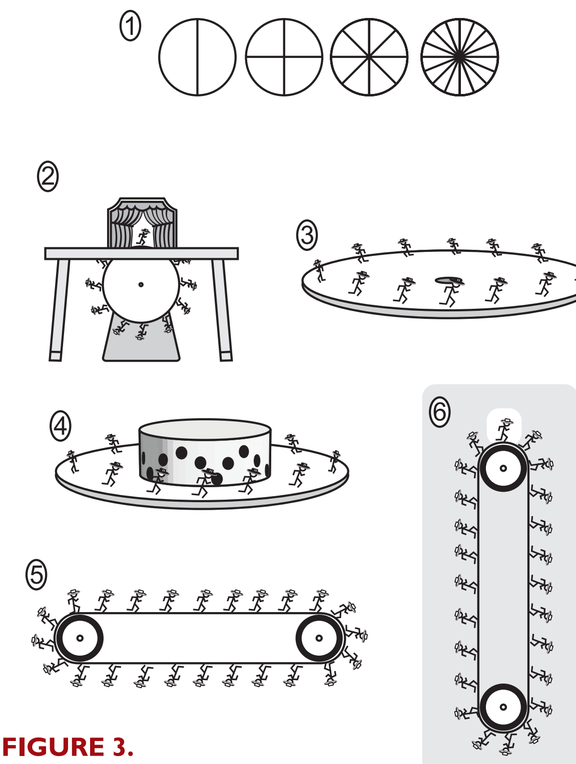


FIGURE 3.

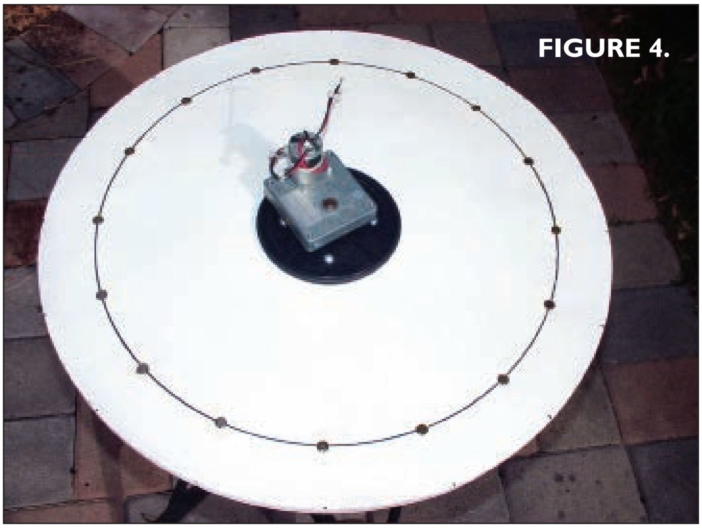


FIGURE 4.

angles until you reach 16 total triangles. This simple method can be used to create equal spacing in wheels with animations of eight, 16, 32, or more frames.

After centering and mounting your wheel to your motor platform, run it briefly while holding the tip of a sharpie pen about 1″ in from the edge against the underside of your disk. This will create a perfect circle on the underside with regard to your wheel's true center, and provide an accurate guide for placing your neodymium magnets (see **Figure 4**). My disk used magnets 5/16″ diameter x 1/8″ thick, though many other sizes will work with a reed switch.

To complete your disk, glue the magnets along the circle you just made at equal spacing; place one magnet under each segment line drawn previously. For extra strength and aesthetics, I drilled a seat for each magnet that made it flush with the bottom of the board.

Easy Way to a Custom Size

If you'd like to create a wheel with a custom diameter, here is an easy way to determine the best size for your animation:

- Start with the width of the object you'd like to animate and allow approximately 1/2″ on either side for spacing. This number becomes your frame size.
- Decide how many frames you'd like to show.
- Multiply the number of frames by the frame size to get the perimeter of the circle.
- Divide by Pi (3.1416) and you have the diameter of your circle to cut.

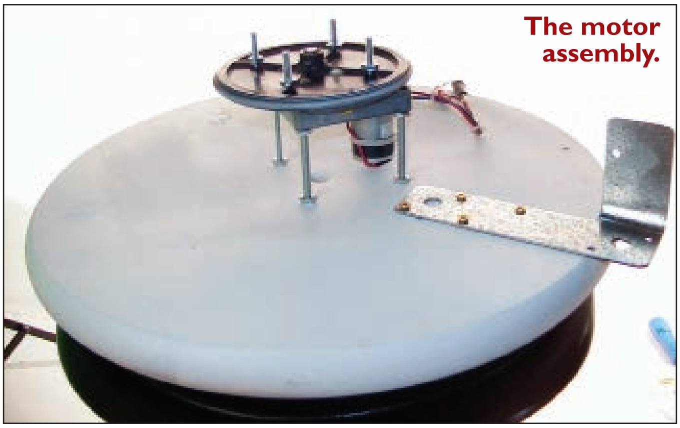
You can also do these steps in reverse if you have a ready-made circle and want to calculate a frame/section size.

There are many free CAD programs on the Web that can simplify a custom wheel by printing out a cutting pattern for you. One good one is at **emachineshop.com**.

The Motor and Base

A 30 RPM motor will give us two seconds of animation which is great for a zoetrope. I would highly recommend a motor that allows you to control speeds between 30 and 50 RPM. An AC motor is usually quieter, but I found a DC motor with a plate already attached which made only a gentle whirring (and allowed me to run the zoetrope on batteries as well).

The wooden base is simply an unfinished "table top" piece which is sold at stores like Lowe's or Home Depot for about $6.



The motor assembly.

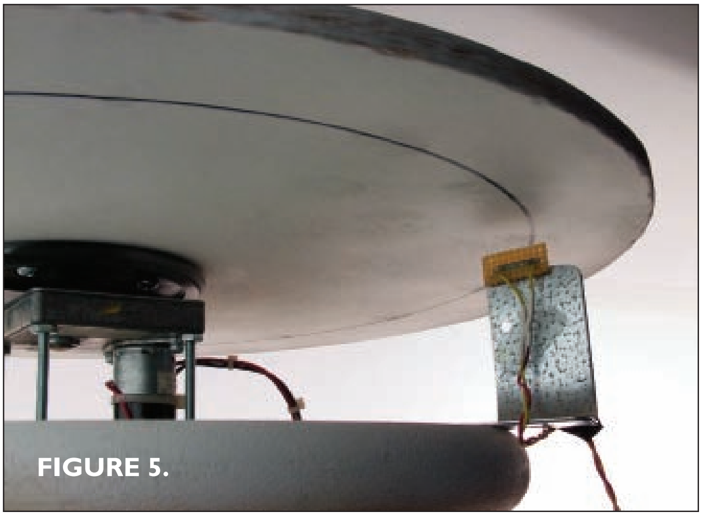
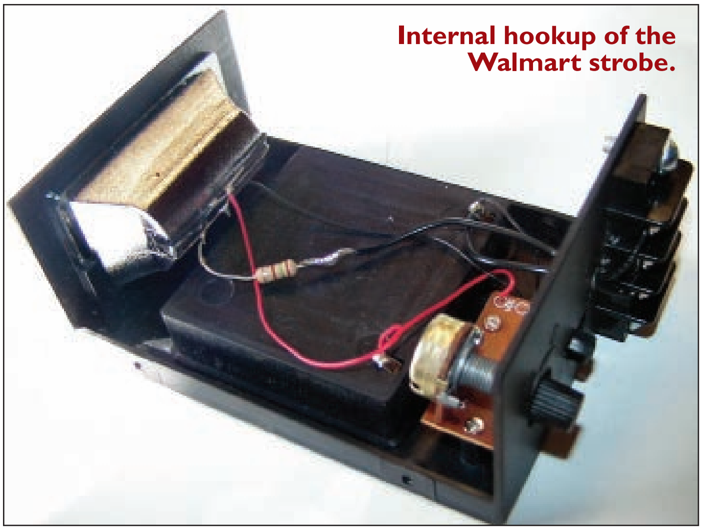


FIGURE 5.

Reed Switch and Strobe

Figure 5 shows the magnetic reed switch under the spinning platform, aligned with the path of the magnets. Modern reed switches typically can handle up to a full amp of current. This makes it possible to trigger a strobe light directly from your reed switch with no other electronics necessary. It's even possible to use ultra bright LED strobes to illuminate your disk. Check out Ramsey Kits "LEDS20" (**www.ramseykits.com**) or, for fun, I modified a $5 Halloween strobe from Walmart (**Figure 6**) which did a passable (though unspectacular) job.

FIGURE 6.



Internal hookup of the Walmart strobe.

In evaluating different strobe lights with the zoetrope, I found that nearly anything worked fairly well and you could stop right at this point in the design and have a fine project. However, truly amazing results can be achieved with a little extra control of your strobe's flash duration.

Typical xenon strobes have a very brief flash duration. This gives a very clear image, but a "flickery" feeling and some dimming of the animation. LED-based strobe panels tend to blur the images due to the fact that the objects in motion were illuminated a little too long.

By creating a simple circuit to precisely control the duration of the flash of an LED-based strobe, we have the best of both worlds. In adjusting the circuit, you can literally watch your animation come into sharp focus which is a kick!

Electronics

Figure 7 shows the 4013 strobe control circuit which is simple enough for perfboard construction (see **Figure 8**). The 500K potentiometer and .01 capacitor determine the exact duration of each flash of your strobe. (The 500K pot can be replaced by a 300K fixed resistor in most cases if you prefer non-adjustable.) The 2n2222 transistor can be any general-purpose transistor for driving small LED lights, or I would recommend substituting a MOSFET for driving larger LED panels or lights. My favorite inexpensive light for the strobe has simply been a super bright LED flashlight (often less than $10).

Since I wanted to use the flashlight's own batteries, I connected a reed relay (shown) to the circuit's output and used the reed relay to close the flashlight's switch contacts. I would highly recommend the relay when experimenting with different light sources (xenon to LED) since nearly anything can be triggered by it.

Animation Basics

So, your wheel is spinning, your strobe is flashing above your wheel, and you're ready to create some visual magic! It's time to turn off the lights and start the show!

A number of ready-made 2D animations make excellent tests for your wheel and strobe. You can find these on the Internet under "flipbook" animations. I've also set up a few that can be printed and cut out free of charge, along with a video of the zoetrope in action at **www.nutsvolts.com** or **www.noonco.com/zoetrope**.

In addition, any posable 3D figure can be animated. Simply mount one copy of your figure on each segment line on the top of your wheel, and create a "looping" animation by creating a series of moves that repeat naturally with the number of frames you have

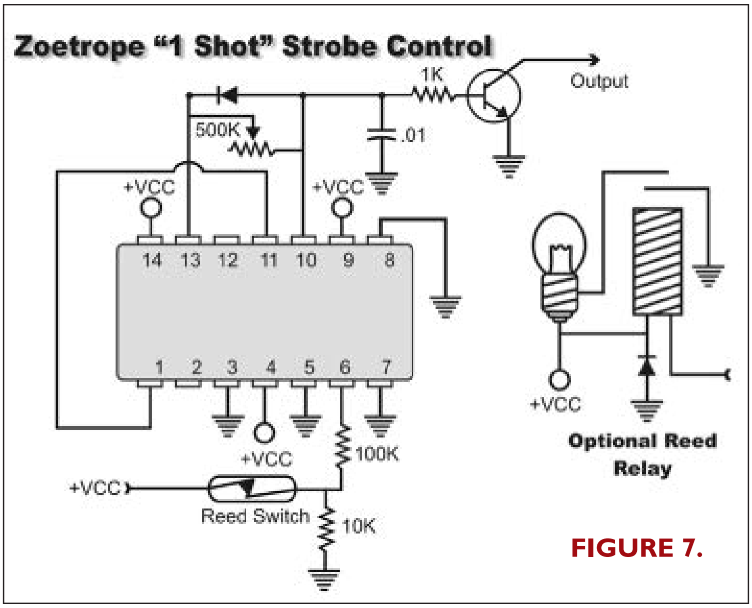


FIGURE 7.

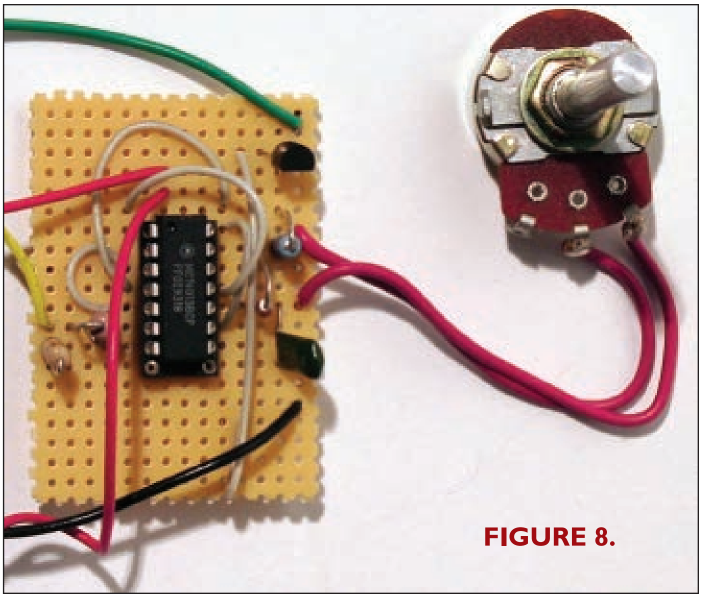


FIGURE 8.

chosen. (This is called an animation cycle.) Your character can seem to walk, jump, or gesture in any way you choose.

A great trick I came up with for animating hard rubber toys was to boil them on the stove. Remove them while they're still hot and pliable by wearing gloves, pose them, and hold them under ice water till they solidify again. I used this method to make sharks swim. Do this with caution, however! It worked wonderfully for my sharks, but may well be destructive to other toys! Test one first.

For temporary mounting of characters and general experimenting, museum wax or other temporary sticky putties work great. I also think a wonderful toy could be made by permanently mounting a highly poseable figure (like an artist's wooden mannequin) at each spot on the wheel for creating animations on the fly as a conversation piece, super toy, or just a bit of magic for your shop. (As long as the models are stiff enough to handle the angular momentum generated by your wheel.) Of course, complex and beautiful animation can be made if you have some sculpting or modeling skills.

There really is no limit, except in the number of frames in which you have to be creative. I keep thinking it's like an animation haiku!

PARTS LIST

ITEM	DESCRIPTION
Electronics	
IC1	4013 flip-flop
Q1	2N2222 (see text)
D1, D2	1N4004
R1	10K ohm 1/4 watt
R2	100K ohm 1/4 watt
R3	1K ohm 1/4 watt
R4	500K ohm potentiometer
C1	.01 µf ceramic capacitor
S1	N.O. magnetic reed switch (small, high speed, 1A rhodium recommended for direct switching)
Bat	3-18V (supply voltage)
Misc. Perfboard	
(Optional 12V, .5A, SPST reed relay for external switching)	
Mechanical	
(16) Neodymium magnets 5/16" x 1/8"	
30-50 RPM motor (any applicable type)	
1/4" particle board cut in 19" circle	
16" unfinished table top	
Parts Supplier	
Parts available at **www.noonco.com/zoetrope**	

Taking It Further

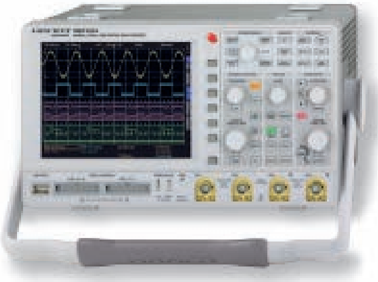
There are no hard and fast rules as to how your zoetrope could be layed out. **Figure 3** shows some additional ideas I'm looking forward to experimenting with. These include a table which hides all but one character (who would seem to be standing on the table when animated by strobe) and also a cylinder which would allow you to put animated 2D painted backgrounds behind your 3D subject.

I hope you have as much fun with your zoetrope as I have, and that you'll send me a video when you do! **NV**

GREAT VALUE IN TEST & MEASUREMENT

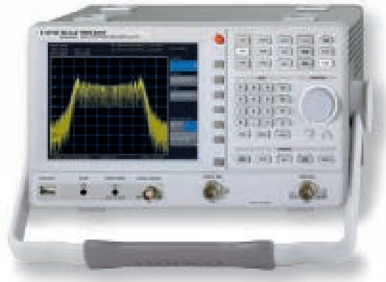
Call for educational discount

350 MHZ 2/4 CHANNEL DIGITAL OSCILLOSCOPE HMO 3522/HMO 3524



- ☑ 4 GSa/s Real time, 50 GSa/s Random sampling, low noise flash A/D converter (reference class)
- ☑ 2 MPts memory per channel, memory Zoom up to 100,000:1
- ☑ MSO (Mixed Signal Opt. HO 3508/HO 3516) with 8/16 logic channels
- ☑ Vertical sensitivity 1 mV...5 V/div. (into 1 MΩ/50 Ω) Offset control ±0.2...±20 V
- ☑ 12 div. x-axis display range
  20 div. y-axis display range with **V**irtual**S**creen function
- ☑ Trigger modes: slope, video, pulsewidth, logic, delayed, event
- ☑ FFT for spectral analysis ☑ Lowest noise fan
- ☑ 6 digit counter, Autoset, automeasurement, formula editor, ratiocursor
- ☑ Crisp 6.5" TFT VGA display, LED backlight, DVI output

3 GHZ SPECTRUM ANALYZER HMS 3000/HMS 3010



- ☑ Frequency range 100 kHz...3 GHz
- ☑ Amplitude measurement range -114...+20 dBm
  DANL -135dBm with Preamp. Option HO3011
- ☑ Sweep time 20 ms...1000 s
- ☑ Resolution bandwidth 100 Hz...1 MHz in 1–3 steps, 200 kHz (-3 dB)
  additional 200 Hz, 9 kHz, 120 kHz, 1 MHz (-6 dB)
- ☑ Spectral purity < -100 dBc/Hz (@100 kHz)
- ☑ Video bandwidth 10 Hz...1 MHz in 1–3 steps
- ☑ Tracking Generator (HMS 3010) -20 dBm/0 dBm
- ☑ Integrated AM and FM demodulator (int. speaker)
- ☑ Detectors: Auto-, min-, max-peak, sample, RMS, quasi-peak

PROGR. 2/3/4 CHANNEL HIGH-PERFORMANCE POWER SUPPLY HMP SERIES

- ☑ HMP2020: 1 x 0...32 V/0...10 A 1 x 0...5.5 V/0...5 A, max. 188 W
- ☑ HMP2030: 2 x 0...32 V/0...5 A 1 x 0...5.5 V/0...5 A, max. 188 W
- ☑ HMP4030: 3 x 0...32 V/0...10 A, max. 384 W
- ☑ HMP4040: 4 x 0...32 V/0...10 A, max. 384 W
- ☑ 188/384W output power realized by intelligent power management
- ☑ Low residual ripple: < 150 μV_{rms} due to linear post regulators
- ☑ High setting- and read-back resolution of up to 1 mV/0.2 mA
- ☑ HMP4030/HMP4040: Keypad for direct parameter entry
- ☑ Galvanically isolated, earth-free and short circuit protected output channels
- ☑ Advanced parallel- and serial operation via V/I tracking
- ☑ EasyArb function for free definable V/I characteristics
- ☑ FuseLink: individual channel combination of electronic fuses
- ☑ Free adjustable overvoltage protection (OVP) for all outputs
- ☑ All parameters clearly displayed via LCD/glowing buttons

25/50 MHZ ARBITRARY FUNCTION GENERATOR HMF2525/HMF2550

- ☑ Frequency range 10 μHz...25 MHz/50 MHz
- ☑ Output voltage 5 mV_{pp}...10 V_{pp} (into 50 Ω) DC Offset ±5 mV...5 V
- ☑ Arbitrary waveform generator: 250 MSa/s, 14 Bit, 256 kPts
- ☑ Sine, Square, Pulse, Triangle, Ramp, Arbitrary
  waveforms incl. standard curves (white, pink noise etc.)
- ☑ Total harmonic distortion 0.04 % (f < 100 kHz)
- ☑ Burst, Sweep, Gating, external Trigger
- ☑ Rise time <8 ns, in pulse mode 8...500 ns variable-edge-time
- ☑ Pulse mode: Frequency range 100 μHz...12.5 MHz/25 MHz,
  pulse width 10 ns...999 s, resolution 5 ns
- ☑ Modulation modes AM, FM, PM, PWM, FSK (int. and ext.)
- ☑ 10 MHz Timebase: ±1 ppm TCXO, rear I/O BNC connector
- ☑ Front USB connector: save & recall of set-ups and waveforms
- ☑ 3.5" TFT: crisp representation of the waveform and all parameters

LCR-BRIDGE HM8118

incl. HZ188

- ☑ Basic Accuracy 0.05 %
- ☑ Measurement functions L, C, R, |Z|, X, |Y|, G, B, D, Θ, Δ, D, M, N
- ☑ Test frequencies 20 Hz...200 kHz
- ☑ Up to 12 measurements per second
- ☑ Parallel and Series Mode
- ☑ Binning Interface HO118 (optional) for automatic sorting of components
- ☑ Internal programmable voltage and current bias
- ☑ Transformer parameter measurement
- ☑ External capacitor bias up to 40 V
- ☑ Kelvin cable and 4 wire SMD Test adapter included in delivery
- ☑ Galvanically isolated USB/RS-232 Interface, optional IEEE-488

1,2 GHZ/3 GHZ RF-SYNTHESIZER HM8134-3/HM 8135

- ☑ Outstanding Frequency range 1 Hz...1,2 GHz/3 GHz
- ☑ Output power -127...+13 dBm/-135...+13 dBm
- ☑ Frequency resolution 1 Hz (accuracy 0.5 ppm)
- ☑ Input for external time base (10 MHz)
- ☑ Modulation modes: AM, FM, Pulse, Φ, FSK, PSK
- ☑ Rapid pulse modulation: typ. 200 ns
- ☑ Internal modulator (sine, square, triangle, sawtooth) 10 Hz...150 kHz/200 kHz
- ☑ High spectral purity
- ☑ Standard: TCXO (temperature stability: ±0.5 x 10^{-6})
  Optional: OCXO (temperature stability: ±1 x 10^{-8})
- ☑ Galvanically isolated USB/RS-232 Interface, optional IEEE-488
- ☑ 10 configuration memories including turn-on configuration

HAPRO Electronics

Tel: +1-516-794-4080 · Fax: +1-516-794-1855 · sales@haproelectronics.com

www.hameg.com

HAMEG® Instruments
A Rohde & Schwarz Company

TRUE-READING AUTOMOBILE GAS GAUGE

By Dan Gravatt

I've never owned a car with a gas gauge that worked right. Even on my 2005 pickup truck, the second half of the tank appears to disappear much faster than the first, and when my low fuel light comes on I still have several gallons left in the tank. The problem with the fuel gauges in most vehicles isn't the gauge itself but the float sensor in the gas tank which isn't any more sophisticated than the float valve in your toilet tank. I set out to build a gas gauge for my truck which tells me exactly how much gas I have in the tank.

Measurement Methods

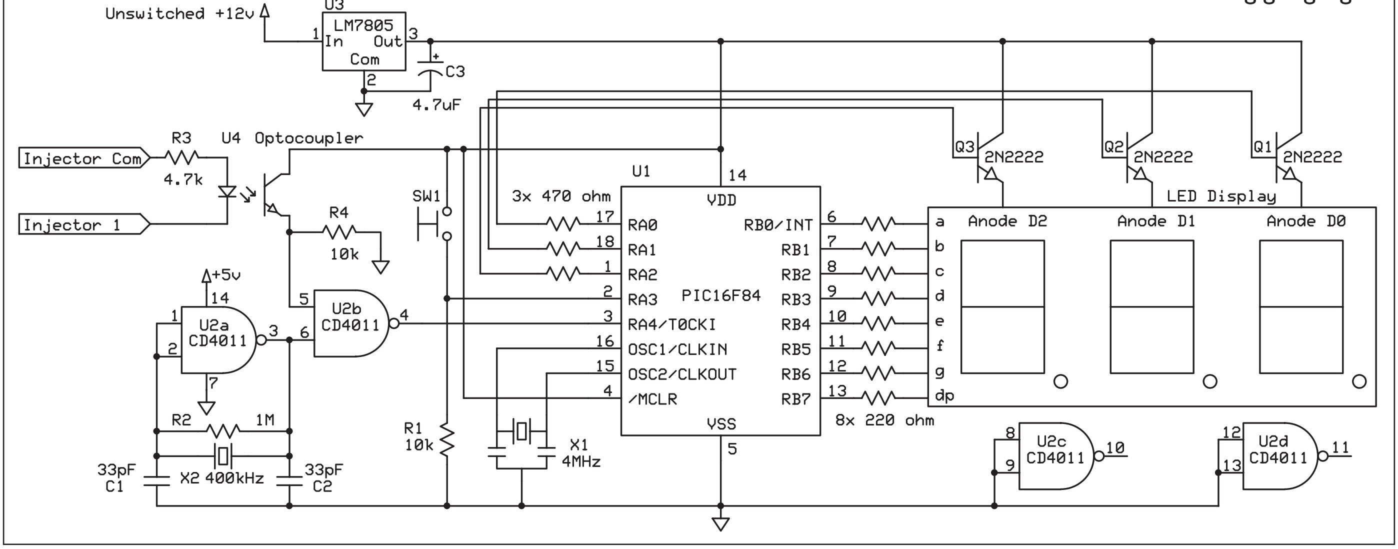
Automakers use float sensors in the gas tank because they are simple and cheap. An accurate measurement of the gas in the tank requires a flowmeter — a device which can directly measure the amount of fuel flowing through it. Actually, three flowmeters would be required: one to measure how much fuel you pump into the tank, one to measure how much is flowing from the tank to the fuel injectors, and one to measure how much fuel returns from the injectors to the gas tank. This last flowmeter is necessary because many vehicles have a fuel return line that routes surplus fuel not used by the injectors back to the tank. Although this setup would be quite accurate, it would be difficult and dangerous to install, as well as very expensive.

After some thought, I realized that the vehicle already has flowmeters on-board which can be used to measure fuel flow — the fuel injectors themselves. Fuel injection systems work by maintaining a constant fuel pressure at the injectors, and varying the amount of fuel squirted into each cylinder through pulse-width modulation of the injector solenoid coils. Fuel injectors have a design flowrate which is specified in pounds per hour (lb/hr) or cubic centimeters per minute (cc/min). If we measure and sum the pulse widths of all of the injectors in real time and we know the injector flowrate, we can calculate how much fuel is consumed in a given time, and how much remains in the tank.

Rather than measure the pulse widths at each injector individually, I chose a simpler approach of measuring the pulse widths at only one of the injectors and then multiplying the calculated fuel consumption for that injector by the number of injectors in the engine (one per cylinder, except for some older vehicles which may have only one injector in the throttle body). This cuts way down on the amount of wiring you'll need to tap into under the hood. I decided to use an opto-coupler between the fuel injector wiring and the measurement circuit for two reasons: to interface the 12 volt injector wiring to the five volt measurement circuit, and to make sure that the measurement circuit can't interfere with the injector operation.

Circuit Design

Our true-reading gas gauge circuit needs to do three things: measure the injector pulse width, sum these widths to calculate the fuel consumption, then calculate and display the remaining amount of fuel in the tank. This approach allows us to calculate the amount of fuel in the tank to the nearest tenth of a gallon (or better). A digital display is called for to take advantage of this level of accuracy. I chose a PIC16F84 microcontroller for this project based on the modest processing workload and I/O pin count required.



■ **FIGURE 1.** Schematic for the true-reading gas gauge.

There are two ways to measure the fuel injector pulse width: directly using some sort of timer, or indirectly using an external reference frequency and a counter. PICBASIC PRO (from microEngineering Labs) contains a PULSIN command which can be used to directly measure pulse duration, but while the PIC is doing this it can't be doing much of anything else. Since we need to measure pulses and update the display concurrently, the indirect measurement method is used. This circuit (**Figure 1**) uses an external 400 kHz reference oscillator and a NAND gate which only feeds the reference frequency to the counter during each fuel injector pulse. Timer 0 in the PIC is used as the counter, and the TMR0 interrupt is enabled in the code (Listing 1, which is available at **www.nutsvolts.com**) so that the pulses can be counted between commands to drive the digital display. I do not recommend using a frequency higher than 400 kHz because of the time needed to turn on each multiplexed LED digit via the PAUSEUS command. The PAUSEUS time was set short enough so that at 400 kHz, the code will not miss an interrupt while driving the display.

A three-digit, common anode LED display is used for this project. Although it uses more power and more I/O lines than an LCD, it generates its own light rather than needing a backlight, and has a bigger character size for easy reading. The 220 ohm series resistors limit the display current so that the PIC doesn't exceed its current limit of 100 mA for port B.

A single Reset button is included in the circuit. When pressed for two seconds or more (to guard against accidental resets), it resets the counter and display to the maximum capacity of your gas tank. This button is the main limitation of my simplified flowmeter implementation – you have to fill the tank all the way each time you gas up, and you have to remember to push the Reset button afterwards. While this is not a bad tradeoff for avoiding the complexity of the three-flowmeter system I described earlier, if you want to put gas in your vehicle $10 dollars at a time, this circuit won't work for you.

Doing the Math

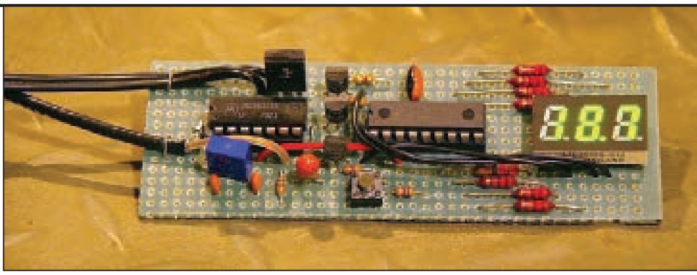
While the calculations needed to convert the summed pulse widths into gallons are only basic arithmetic, they involve numbers much larger than can be represented in a 16-bit word and are therefore difficult to implement with the PIC16F84. To get around this, I created a simple spreadsheet (available at **www.nutsvolts.com**) which distills the entire calculation down to one value which is then entered into the code as a preset for the Pulsecount variable. All you need to know is the flowrate of your injectors in cc/min, the number of cylinders, and the frequency of your reference oscillator.

As timer 0 counts pulses from the gated reference oscillator, it will roll over from 255 to 0 periodically and generate an interrupt. The PICBASIC interrupt service routine (ISR) increments the Pulsecount variable at each interrupt, and then checks to see if Pulsecount (a word-sized variable) has reached its preset value. The calculations in the spreadsheet are set up so that each time Pulsecount reaches its preset value, 0.1 gallon of fuel has been used, and the ISR will decrement the gallons variable accordingly.

Be sure to look at the spreadsheet and the code in **Listing 1** which include numerous comments to better explain how everything works and where you'll need to change values (such as your gas tank capacity) for your particular vehicle. You will need a copy of PICBASIC PRO (**www.melabs.com**, the free demo version will work too) to recompile the code once you have made your changes.

Injector Information Sources

By now, you're probably wondering where you are



■ **FIGURE 2.** My prototype gas gauge circuit.

going to find the flowrates for your vehicle's fuel injectors. The bad news is that it may not be in the service manual. The good news is that you can probably get this information from your car dealership or from one of the big-name auto parts dealers in town. If they can't get you the flowrate but can at least provide you the part number and manufacturer for your fuel injector, you can probably track it down on the Internet.

Installation

The interface between the vehicle's electrical system and the gas gauge circuit is very simple, requiring only two connections for the opto-coupler and two for the power to the circuit. Most fuel injection systems have a common 12 volt connection to all of the injectors and

LISTING 1

```
'*******************************************************
'* Name        : gasgauge.pbp                           *
'* Author      : Dan Gravatt                            *
'* Version     : 1.1, code validated and appears good  *
'* Notes       : True-reading gas gauge using 16F84     *
'*             : Sums fuel injector pulse durations to calculate flowrate*
'*******************************************************

'Uses 3-digit, seven-segment LED display, ##.# gallons
'Uses external oscillator and logic gate to count oscillations while injector is energized
'Uses TMR0 with external frequency input on
RA.4 to count oscillations
'Include a day/night brightness setting?  CdS with transistor to parallel a resistor with LEDs to dim
them?
'Route constant power to PIC, switched power to the LEDs.
'full tank reset button, push & hold 2 sec to reset, on RA.3
'PortB.0-7 connected to each LED display digit, segments a-g plus DP, respectively
'PortA.0-2 connected to digit display drivers, digits 2,1,0 right to left

option_reg = %11101000              'sets TMR0 to external count on RA.4, no prescaler
intcon = %10100000                  'enables TMR0 overflow interrupt
trisb = 0                           'PortB all outputs for LED driving
trisa = %11111000                   'Sets PortA.0-2 to outputs for LED driving, PortA.3-4 inputs
pulsetime var word                  'stores running total of TMR0 overflows
gallons var word                    'stores current gallons of gas remaining, in tenths
digitz var byte[3]                  'stores digits for display
loope var byte                      'loop counter variable
on interrupt goto overflow
data 192,249,164,176,153,146,130,248,128,144
              'active low LED segment patterns for decimal digits 0-9, stored in EEPROM during programming

main:
if porta.3 = 1 then fulltank        'checks if reset button has been pressed
for loope = 0 to 2
digitz[loope] = gallons dig loope   'parse gallons into individual digits for LED display
read digitz[loope], portb           'reads the segment pattern for the decimal digit and applies it to
                                    'PortB
if loope = 1 then portb.7 = 0       'illuminates decimal point for second digit only
if loope = 2 and digitz[loope] = 0 then portb = 255       'blanks leading zero
porta = dcd loope                   'activates digit driver for selected LED digit
pauseus 500                         'pause for 500uS or 0.5mS to minimize missed interrupts
porta = 0                           'blanks display between digits
next
goto main

fulltank:                           'subroutine to reset to max gallons when tank filled
pause 2000                          'requires user to hold button for 2 seconds to reset
if porta.3 = 1 then gallons = 200   'Canyon full tank is 20 gallons
if porta.3 = 1 then pulsetime = 0   'initializes pulsetime variable
goto main

disable
overflow:                                   'TMR0 interrupt handling routine
pulsetime = pulsetime + 1                   'increments number of overflows, each represents
                                            '256 oscillations
if pulsetime = 29830 then gallons
  = gallons - 1               'when pulsetime reaches this calibrated value, 0.1 gallon has been used
if pulsetime = 29830 then pulsetime = 0     'calibrated so that X * 256 oscillations at 401 kHz equals
0.1 gallon
intcon.2 = 0                                'clears TMR0 interrupt flag
resume
enable
```

Dan Gravatt can be reached at dgravatt@juno.com.

individual ground wires for each injector. Carefully tap into the common 12 volt wire and one of the individual injector ground wires, and install the LED side of the opto-coupler and its series resistor across these two wires in the proper polarity orientation. You'll need a service manual or other technical information source on your vehicle to verify the location and identity of these wires, and to confirm that the wiring polarity to the injectors matches the description here. Tightly tape up or seal the connections to the vehicle's wiring to prevent moisture entry and corrosion.

The power to the gas gauge circuit must be unswitched power (i.e., power that is on even when the key is removed) so that the PIC can remember the gallons remaining in your tank. This means that the display will also be on all the time. If you don't like this, you can add a separate five volt regulator for the collectors of the three display driver transistors Q1-Q3 and connect the voltage input for this regulator to a switched power source in your vehicle. My prototype gas gauge circuit is shown in **Figure 2**. I recommend building yours in an enclosure; Serpac makes some nice translucent-color enclosures which allow the LED display to shine through without having to cut a rectangular hole for it.

After you fill your gas tank and apply power to the circuit for the first time, press the Reset button for more than two seconds to properly initialize the Gallons and Pulsecount variables, and you're ready to go.

Fudge Factor

If the amount of fuel your gas gauge says you have used doesn't match the amount of fuel you put into the tank at your next fill-up, there could be a couple of explanations. If the amounts are very different, you may have bad information on your fuel injector flowrates, or you may have made a math error entering data for your vehicle into the spreadsheet. Also check to make sure you properly modified the variables in the PIC code.

If the amounts are close but don't quite match, your reference oscillator may not be oscillating at exactly 400 kHz, or the fuel system in your vehicle may be operating at a different pressure than the pressure for which your fuel injectors are calibrated. Try measuring the oscillator frequency and entering the exact value into the spreadsheet. If you just can't track down the source of a minor inaccuracy in your gas gauge, but the difference is constant over time (always a few percent high, for example), you can calculate a "fudge factor" and adjust the preset value for the Pulsecount variable accordingly. Time to fuel up! **NV**

PARTS LIST

ITEM	DIGI-KEY PART#
PIC16F84 microcontroller	PIC16F84A-04/P-ND
CD4011 quad CMOS NAND gate	CD4011BCN-ND
LM7805 five volt regulator	296-21619-5-ND
LTV-816 opto-coupler	160-1360-5-ND
4 MHz ceramic resonator	490-1208-ND
400 kHz ceramic resonator	490-1186-ND
(3) 2N2222 NPN transistors	P2N2222AGOS-ND
Three-digit common-anode red LED display	160-1544-5-ND
(8) 220 ohm 1/4 watt resistors	220QBK-ND
(3) 470 ohm 1/8 watt resistors	470EBK-ND
4.7K ohm 1/4 watt resistor	4.7KQBK-ND
(2) 10K ohm 1/8 watt resistors	10KEBK-ND
1M ohm 1/8 watt resistor	1.0MEBK-ND
(2) 33 pF ceramic capacitors	490-4157-ND
4.7 µF 25 volt tantalum capacitor	399-3559-ND
Momentary SPST pushbutton switch	CKN9098-ND
Translucent red enclosure (optional)	SCR8TR-ND

USB AND THE 32-BIT MICRO EXPERIMENTER

BY THOMAS KIBALO

In this article, we will explore the use of the 32-bit Micro Experimenter and USB. The Experimenter is equipped with a USB hardware interface and this, along with the use of Microchip's USB software stack, will allow us to use the Experimenter in a variety of USB device applications. We'll embark on somewhat of a deep dive into Microchip's USB framework, but we promise it will be worth it. After following our directions/reading the article/trying the experiments, you will have an understanding of how to use the Experimenter in a number of different USB device roles, such as a mouse, a serial port, and a Flash drive. Again, as in all articles in this series, a general familiarity with C language is required.

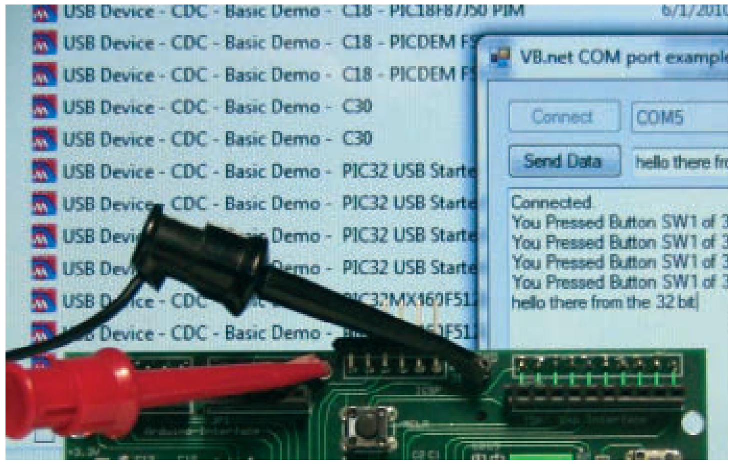


FIGURE 1. The 32-Bit Experimenter and USB.

USB — History And Overview

Let's start with a little history and some background. USB or Universal Serial Bus was co-developed by a number of large companies including Microsoft and Intel with the explicit purpose of making it easier to add/remove peripheral devices from a PC. If you remember not too far back in time, the older generation of PC device peripherals had their own special-purpose serial communication ports, parallel printer ports, or PS/2 for keyboards. Today, all of that is gone with USB. USB 1.1 released in 1998, followed by USB 2.0 in 2000 has become the de facto standard for PC peripheral device interfaces. To address the particular needs for a large number of peripheral devices, USB introduced the concept of "Device Classes." These are:

- Human Interface Device Class (HID) – joystick, mouse, keyboard.
- Mass Storage Device Class (MSD) – external hard drives.
- Communication Device Class (CDC) – modems, Ethernet adapters.

We will demo the Experimenter as a peripheral device for each one of these classes. We will draw heavily on the USB framework to implement the Experimenter so it will function as a HID mouse, an MSD hard drive, or a CDC serial port. Microchip has done most of the heavy lifting here; you will be surprised how easy this is. Let's cover some more USB theory.

USB devices share the same bus but cannot communicate directly with each other — only with the PC. The PC is a de facto "USB Master," responsible for initializing all peripheral device transfers and for properly servicing all the device's communication needs. This can be a pretty daunting task when you have upwards of 127 devices total (using external USB hub extensions) for a maximum USB configuration. But no worries! USB 2.0 is fast! Full Speed (FS) runs at 12 Mbits/second — a speed that is supported by Experimenter hardware and the Microchip USB Software framework.

USB supports "plug and play" allowing peripheral devices to be hooked up and removed from the bus by the user as needed. In order to do so, the PC as "Master" automatically detects peripheral device extractions and

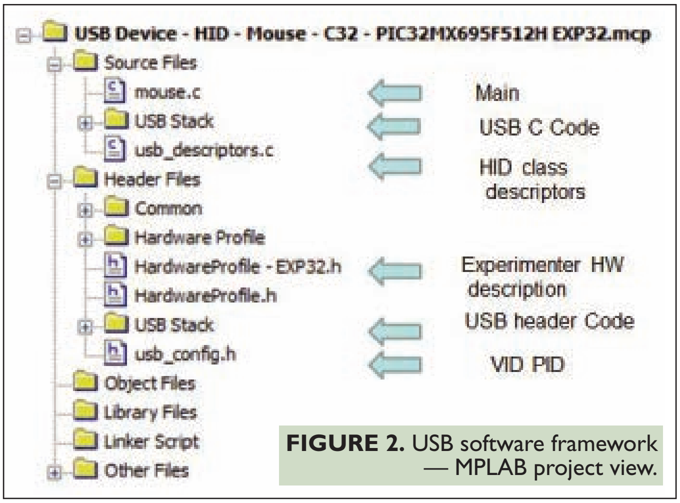


FIGURE 2. USB software framework — MPLAB project view.

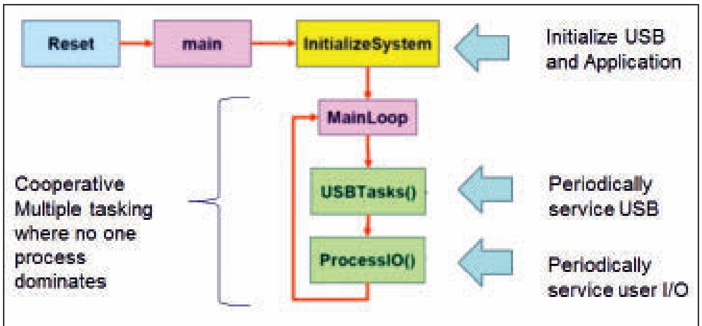


FIGURE 3. Main USB function template.

insertions. Each device — when it is connected to the USB — is "enumerated" by the PC, which means the device identifies to the PC its device type via USB descriptors such as: vendor ID (VID), product ID (PID), class type, operational needs, and driver requirements. The PC checks that it can meet the operational needs and that the identified driver for the device is present in its current software registry. Once all this is accomplished, the PC assigns an address to the device for USB communications.

Every device must have its own unique VID and PID to avoid confusion in this scheme. The VID and PID supplied by the Microchip framework is only available for prototyping and not to be used in a final product. If you contemplate building your own product, then you must register for your own VID/PID with a USB developer's organization.

Demo experiments will use Microchip's VID/PID and the device drivers for HID and MSD that are already in place with the Windows operating system. For CDC, we will use a Microchip supplied registry file (.INF) to register the communication port with the operating system and then use HyperTerminal.

An Overview Of The Microchip USB Stack And USB Peripheral

The Microchip USB framework is similar for all USB applications. The project view MPLAB is captured for the mouse demo.

It is important to note that most of the USB related code is already put in place by the Microchip Framework. What we — as users — focus on is the main function code. There are certain rules to follow to insure that the USB is serviced periodically within the main function. This is done by calling the 'C' function "USBTasks ()" once each time through the main loop. To service our user defined I/O specific for the end application, we need (in addition) to call the 'C' function "ProcessIO ()". Take a look at **Figure 3**.

This is the template structure the framework uses for Main code and the one we will be following throughout our demos. The template arrangement is described as cooperative multitasking and is implemented by using a continuous loop in C code. The user has to insure that the "ProcessIO ()" does not unduly occupy significant CPU processing time where the CPU delays service from the USB for greater than 1.8 milliseconds.

Microchip recommends that the ProcessIO () be implemented as a "state machine design." This means that the required process is broken down into a number of discrete steps where each step consumes only a limited amount of loop time. The state machine keeps track of what steps have been completed and which ones still remain to be done during every pass through the main loop.

Another important component is the USB peripheral hardware. A block diagram is shown in **Figure 4** that captures all the hardware functionality, from PC through USB cable, to Experimenter to PIC32. The peripheral is standard for Microchip's entire USB enabled microcontrollers. Note that the peripheral uses the USB bus supply voltage of +5V to sense the USB bus connection, and to regulate and drive its data lines which

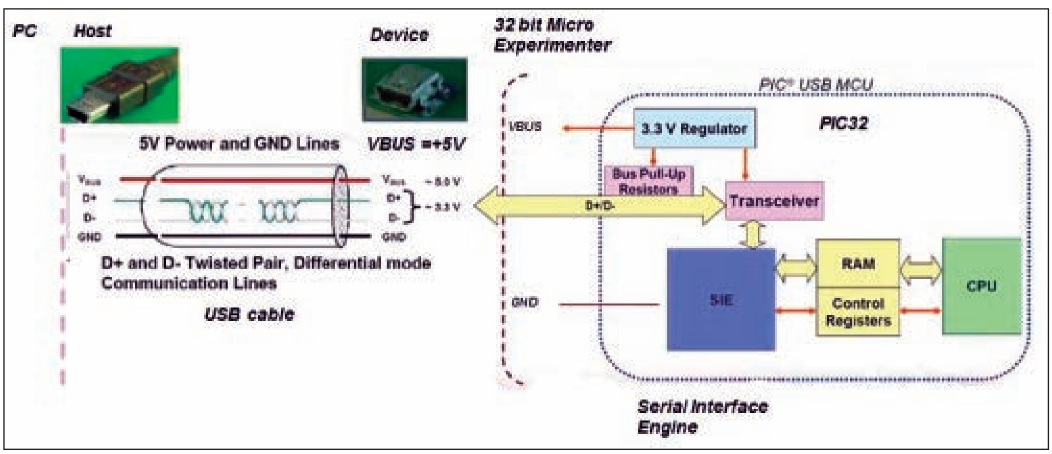


FIGURE 4. Experimenter USB hardware peripheral.

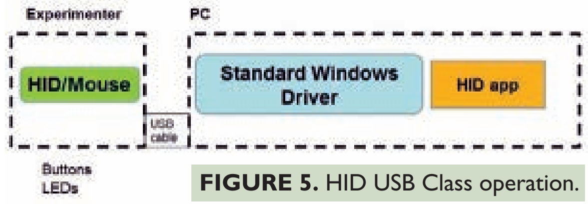


FIGURE 5. HID USB Class operation.

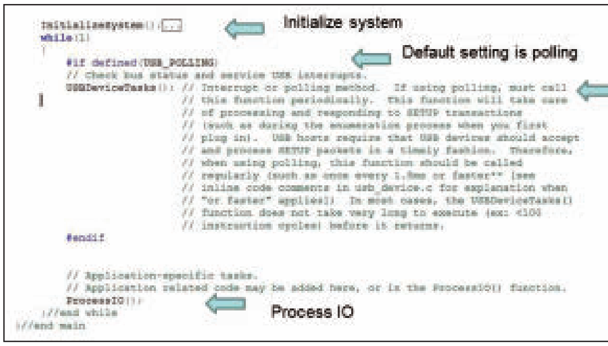


FIGURE 6. Mouse MAIN function.

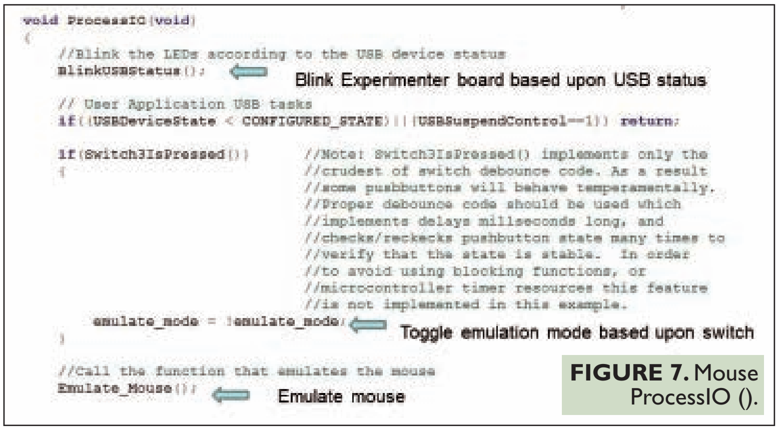


FIGURE 7. Mouse ProcessIO ().

are at a standard +3.3V differential level.

A key hardware component within the USB peripheral is the SIE or Serial Interface Engine. The SIE off-loads the microcontroller CPU by directly handling all USB activity. The SIE communicates to the microcontroller CPU through internal RAM. It automatically does conversions from serial to parallel between serial USB bits and parallel CPU memory, and performs USB communications error checking.

Let's put all this together for several demo applications.

HID Mouse Demo

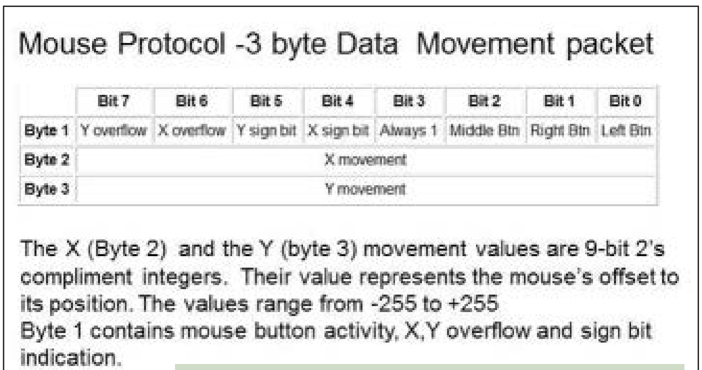
For this demo, the Experimenter will emulate a mouse using the HID Device class (see **Figure 5**). The demo works with standard Window drivers and emulates mouse activities. The word "emulation" is used in that there is no actual mouse-positioning electronics used for this experiment, and all mouse movements are artificially generated.

The demo doesn't eliminate your existing mouse, but instead overlays the existing mouse icon position with a circular rotating arrow icon that moves within the position setting of your real mouse. So as not to be too confused during its operation, you can toggle the Experimenter mouse on and off at any time by pushing SW1. The PC does not know the difference between the Experimenter mouse and your real mouse, and overlays any movements together whether synthesized or real.

To run the demo, make sure power is applied to the Experimenter; connect a PICKIT3 to it, open MOUSEDEMO project, and then compile and download using PICKIT3 as a programmer. Remove the PICKIT3 and hook a USB cable from your PC to the USB connector on the Experimenter. Now sit back and watch the fun. Push SW1 to toggle the emulated mouse on/off. While the Experimenter USB is unconnected to the PC USB, a single LED on the Experimenter is on. When both USB are connected and the Experimenter is performing its HID functions, the Experimenter reacts by toggling both its LEDs on/off.

The main code loop for the mouse demo is shown in **Figure 6**. It follows the USB Main Code template described earlier. Polling USB is simply achieved by calling USBDeviceTasks () once every pass through the main loop. The ProcessIO () function at the end of the main loop is where the mouse emulation occurs. Let's examine both of these code snippets.

The ProcessIO updates Experimenter LEDs based upon USB status and then turns on/off mouse emulation based upon pushbutton SW1. Mouse emulation works in the "streaming mode" where only mouse movement data is reported via HID class to the PC. In other words, no commands are received from the PC. The movement is captured in a three-byte data packet that passes over the USB from mouse to PC as shown. During mouse emulation movement, packet values are preconfigured to have the mouse cursor move in a circular motion relative to the current mouse position. For more details on the mouse emulation, you are encouraged to examine the


Mouse Protocol -3 byte Data Movement packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 1	Y overflow	X overflow	Y sign bit	X sign bit	Always 1	Middle Btn	Right Btn	Left Btn
Byte 2	X movement							
Byte 3	Y movement							

The X (Byte 2) and the Y (byte 3) movement values are 9-bit 2's compliment integers. Their value represents the mouse's offset to its position. The values range from -255 to +255
Byte 1 contains mouse button activity, X,Y overflow and sign bit indication.

FIGURE 8. Mouse data movement packet format.

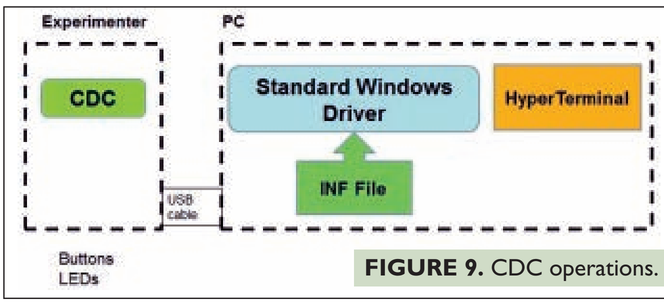


FIGURE 9. CDC operations.

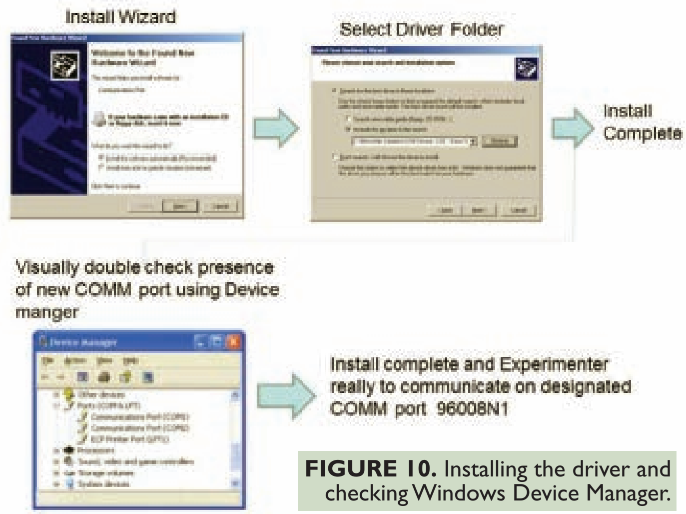


FIGURE 10. Installing the driver and checking Windows Device Manager.

Emulate Mouse function.

It is not a far leap to actually develop a real streaming mode mouse capability here. You would need to add some X, Y positioning electronics to the Experimenter and then move relative position X, Y values in the mouse movement packet for transfer to the PC.

CDC Serial Port Demo

In this demo, the experimenter will emulate a serial port to the PC using a CDC class device. The port will extend the existing COM port portfolio to a new COM port configured at 9600 baud, eight bit, no parity, one stop bit, and with no hardware handshake (9600N81). A block diagram of operations is shown in **Figure 9**.

The most straightforward method to communicate with this port is through HyperTerminal. However, with Windows 7 this capability is no longer standard and a Visual Basic (VB) Net 2008 GUI is available for download. This VB GUI application allows communication with this port. In order to get the Window operating system to recognize a new COM port, a registry file or INF needs to be installed. This is also included as part of the demo software.

Before anything occurs, you need to install the INF files. Windows requires a software driver be installed for each new COM port. The Windows "Install Wizard" offers two possibilities: searching the Web or browsing your computer for the correct driver. The optimal choice is to browse your computer and navigate to the downloaded demo folder where a copy of the INF file is located. Select this driver and direct Windows to do the install. These steps are illustrated in **Figure 10**.

The next step is to use an application that can make

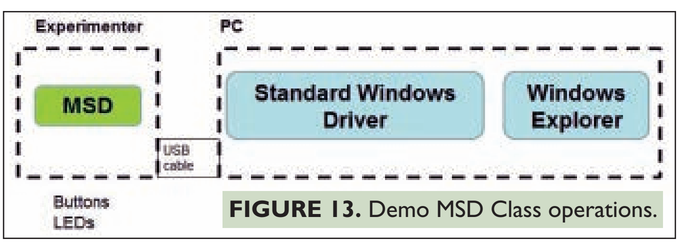


FIGURE 13. Demo MSD Class operations.

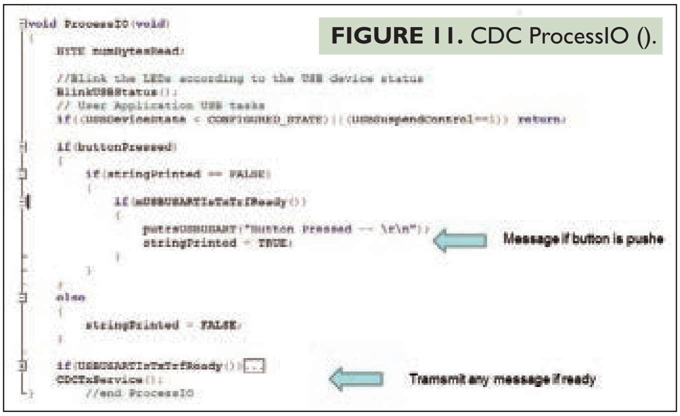


FIGURE 11. CDC ProcessIO ().

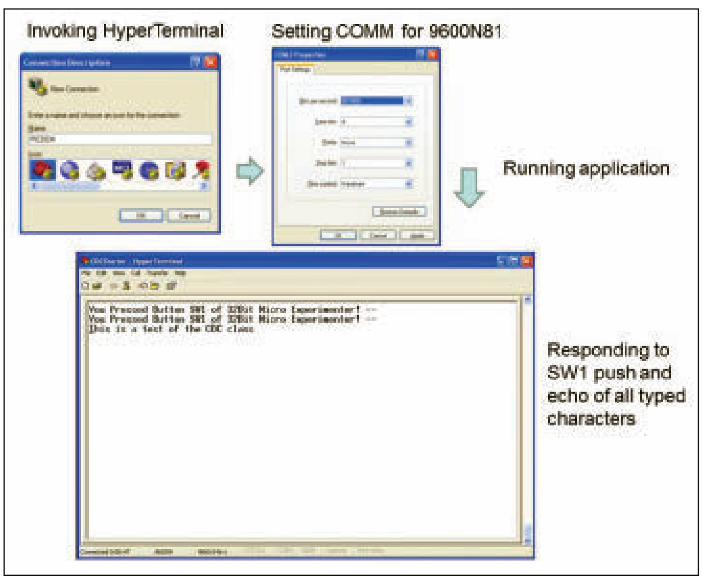
use of the new Experimenter COM port. Two are offered. The simplest one is to use HyperTerminal (this is the one we will cover here). The second you could use is Visual Basic 2008.Net version (VB) that comes preloaded with the demo. The VB version will require you to download and install the Visual Basic Express 2008 edition which is free.

Let's review that "ProcessIO ()" is part of this demo (see **Figure 11**). The ProcessIO () uses an API (Application Programing Interface) for the CDC class that is part of the Microchip framework. Three that are used here are:

- **mUSBUSARTIsTxTrfReady()** - returns one or zero if the CDC class is ready to transmit.
- **putrsUSBUART("string")** – sets up a string to transmit to the PC using the CDC class.
- **CDCTxService()** – transmits any setup data to the PC over USB using the CDC class.

To run, make sure power is applied to the Experimenter, connect a PICKIT3 to it, open SERIALDEMO project, and compile and download into your Experimenter using PICKIT3 as a programmer. Remove the PICKIT3, and hook a USB cable from a USB port on your PC to the USB on the Experimenter. The end result of the application is that every time you press SW1, a canned

FIGURE 12. Using HyperTerminal to test CDC applications.



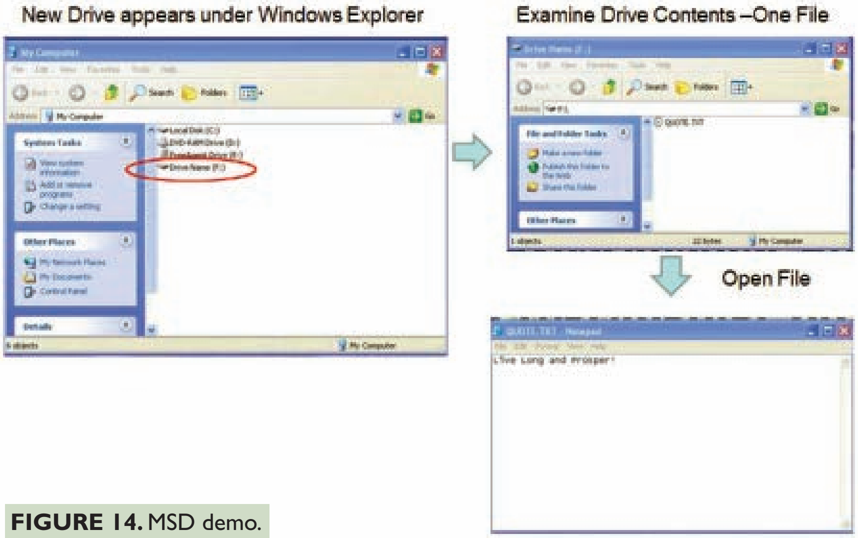


FIGURE 14. MSD demo.

message is send to the PC: "You pressed Button SW1 of 32Bit Micro Experimenter!" As you type in the HyperTerminal window, it echoes back the character you sent. While the Experimenter USB is disconnected from the PC a single LED on the Experimenter is on. When the USB is connected, the Experimenter responds by toggling both its LEDs on/off.

MSD Demo

In this demo, we have the Experimenter functioning as an MSD device over USB, so it emulates a hard drive. We use internal Flash of the PIC32 to function as this drive. When you hook the USB cable from your Experimenter to the PC, the PC will automatically register another drive for access. You can verify this by opening Windows Explorer. The new drive will be the Experimenter emulating a hard drive over USB. Double-click on the drive to open. The content — in this case — is a single file Quote.txt. Double-click this file to view the contents which, in this case, is a "trekkie" quote: "Live long and prosper!" **Figure 14** illustrates this process.

The demo is MSD.MCP; you install it the same way you did with the other demoes.

Where To Go From Here

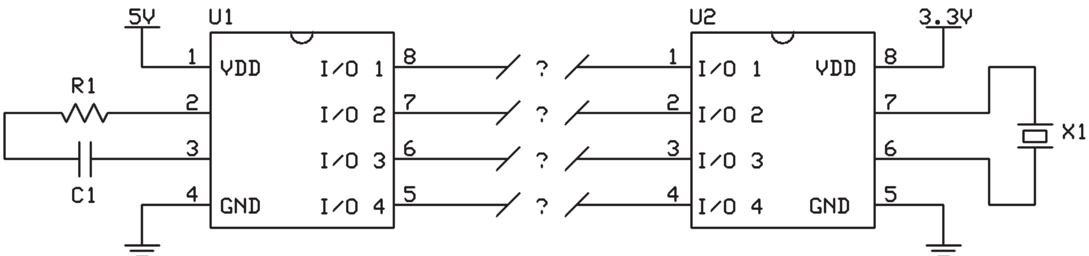
We have covered a lot of ground on Experimenter USB device capabilities. By now, you are familiar with a number of ways to interface your Experimenter via USB to your PC as a mouse, internal Flash drive, or serial port emulation. No additional electronics are necessary other than the standard USB peripheral that is inherent to the entire Microchip USB enabled microcontroller.

A second benefit is that all this is achievable using the Microchip USB software framework. This framework creates a straightforward, easy to use template that facilitates the use of USB in your designs. The demos we discussed should provide the added incentive for you to experiment with this key technology in your future Experimenter designs. Until next time, have fun with 32-bit computing! **NV**

Integrated Ideas & Technologies, Inc.
ITAR Compliant
ISO 9001:2008
AS 9100 Certified
Precision Laser Cut Stencils
Sheet Metal Fabrication
Precision Parts Manufacturing
Defense
Aerospace
Medical
Aviation
Communications
Maritime
Electronics
Serving All Industries
Metal Fabrication: www.iitmetalfab.com
SMT Stencils: www.integratedideas.com

Mixed Voltage Systems —

Interfacing 5V and 3.3V Devices



By Chris Savage

It is common today to find microcontrollers, interface chips, sensors, and other devices in 5V or 3.3V flavors. But what happens when you need to interface a 5V sensor with your 3.3V microcontroller? Devices that operate at different voltages most often do not interface directly to one another. The goal of this article is to provide an understanding of the various options for interfacing signals at different voltages.

Seven methods for interfacing 5V and 3.3V devices will be described. Not all methods can be used in all situations, so it is important to read through all seven sections if this is your first experience with interfacing mixed voltage systems. It is not necessarily important which device in a system is 5V or 3.3V. For each interface method described, the direction of the signals is more important, followed by any considerations of using that interface method in your system.

When interfacing mixed voltage systems, it is helpful to understand that direction also determines the need for protection. For example, a 5V output going into a 3.3V input requires conditioning. However, a 3.3V output going into a 5V input will not since the range of input voltages is within the accepted limits of the 5V device. Furthermore, the logical high and low signals from the 3.3V output should be read properly by the 5V system due to input thresholds for each logic level. On open-collector 3.3V outputs, a pull-up resistor to 3.3V may be required. In the following interface methods, it is assumed that the 5V and 3.3V devices share a common ground unless otherwise specified.

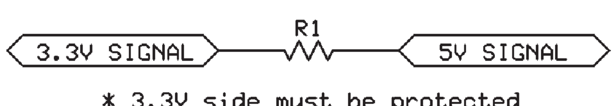


FIGURE 1.

Series Resistor Interface

A series resistor is sometimes used to interface 5V/3.3V devices, however, it is important to understand that not all devices can be connected in this manner. This type of interface requires the 3.3V device to have protection from over-voltage on the I/O pins. This is done using clamping diodes which are designed to limit the input voltage to ~3.3V. These clamping diodes are pretty robust, however, they are not meant to continuously sink large amounts of current. The series resistor limits the current across the clamping diode so that it is not permanently damaged.

Figure 1 shows a series resistor interfacing 5V and 3.3V devices. The value of R1 could vary if you know the current capability of the clamping diodes on your device. To be safe, you could use a 10K resistor. However, larger resistors limit the bandwidth of the signal across them. With higher bandwidth signals, you will need to reduce the size of the resistor. You probably won't go below 1K on most devices.

Not all 3.3V devices are able to be connected in this manner. If your device does not include clamping diodes, you should not use a series resistor to interface to the 5V www.nutsvolts.com/index.php?/magazine/article/april2011_Savage

signal. While the 3.3V device may appear to function, it will eventually fail from electrical stress.

The Propeller chip does include protection, however, the clamping diodes are rated at ±500 µA. To ensure this current limit is not exceeded when providing 5V to an input pin, we must use a minimum resistor value of 2,800 Ω. To allow for some safety margin and the fact that 2.8K is not a standard resistor value, it is recommended to use a 3.3K (minimum) or 4.7K resistor. Both values are available at your local RadioShack store.

Remember, it is not necessary to use a resistor on a 3.3V output going into a 5V input. The bidirectional port tags show that the signal can travel in each direction, but the resistor is only required when the signal is bidirectional or an output from the 5V device. As a convenience, 1K (#150-01020), 4.7K (150-04720), and 10K (#150-01030) resistors are available from Parallax.

Diode Interface

Using a diode to isolate the 5V signals from the 3.3V device can offer a safer method of interfacing, and does not require the 3.3V device to have protection diodes. In this interface, the diode prevents 5V signals from entering the 3.3V device, but allows the 5V device to assert the signal low, ensuring that the 3.3V device only sees 3.3V or 0V (GND). **Figure 2** shows the diode circuit allowing a 5V device to control a 3.3V device. Note R1 which is used to ensure the 3.3V input is high when the 5V device is not asserting the line low. This resistor is needed because the 5V device cannot assert the signal high.

While the diode allows the 5V device to assert the 3.3V device low, the actual voltage of the low signal will be equal to the voltage drop of the diode. It is for this reason that a Schottky diode is typically used in this circuit, as it has a lower forward voltage (typically 0.2V). It is important to be sure the cathode of the diode is toward the 5V device.

Transistor (BJT) Interface

Transistors have long been used to control a larger voltage (or current) with a smaller voltage (or current), essentially acting as an amplifier or switch. When used to condition a signal, a transistor inherently inverts the signal. Still, a transistor provides yet another way to interface signals of different voltages. Within a microcontroller environment, it is easy to compensate for inverted signals in code.

Figure 3 shows how to use a 2N3904 NPN transistor to safely interface to a 3.3V input from a 5V device. As you can see, a pull-up resistor (R2) is required on the 3.3V side. A current limiting resistor (R1) is required on the 5V side. When the 5V output goes high, Q1 will bias pulling the 3.3V side to ground. When the 5V output is low, Q1 is not conducting and R2 pulls the 3.3V side to 3.3V.

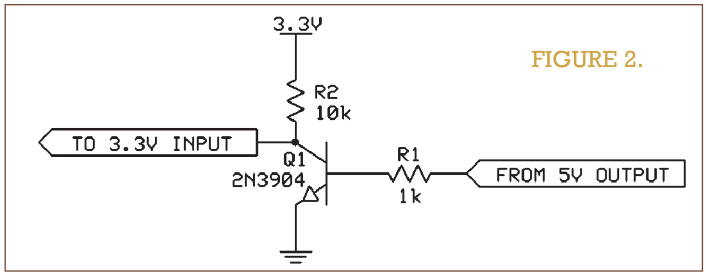


FIGURE 2.

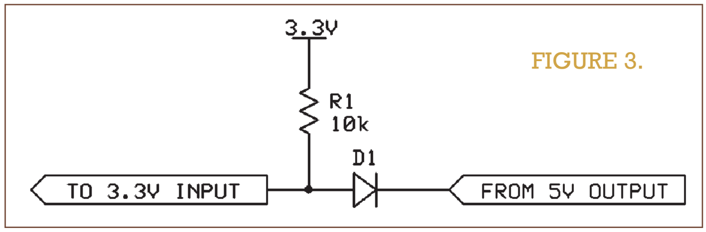


FIGURE 3.

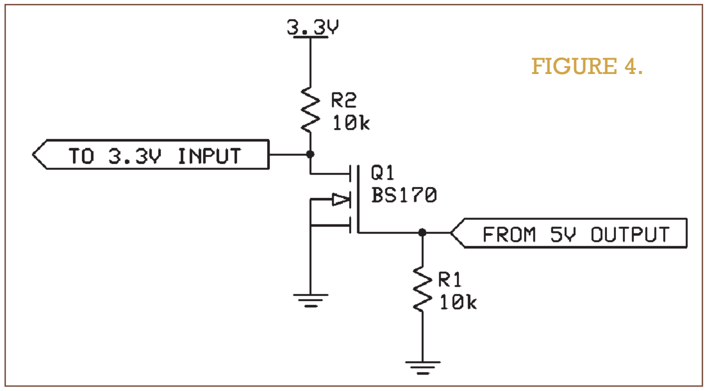


FIGURE 4.

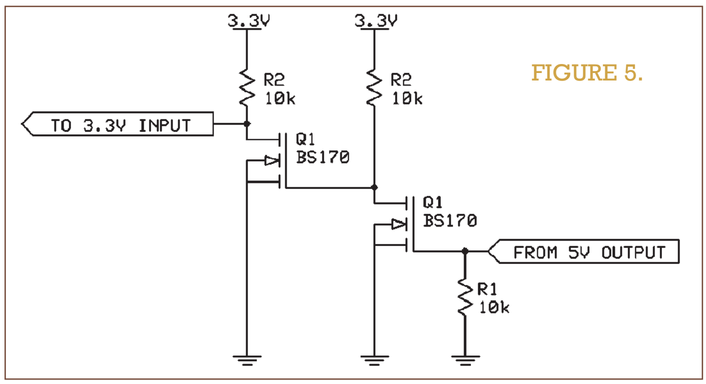


FIGURE 5.

Figure 4 shows the same interface using a BS170 FET instead of a 2N3904 BJT. In this arrangement, R2 is still required to pull up the 3.3V input. However, R1 is now connected to ground to ensure Q1 is off when the 5V output is floating. This can happen on power-up if the pin has not yet been initialized to an output.

While inversion is easily handled in software on a microcontroller, if for some reason you cannot have the signal inverted in your design and want to use the FET design, you can also create a two-stage buffer as shown in **Figure 5**. In this circuit, the signal is double inverted, making the output signal follow the input relative to the voltage supply levels.

Optical Isolation Interface

Optical isolators work just like transistors as far as the

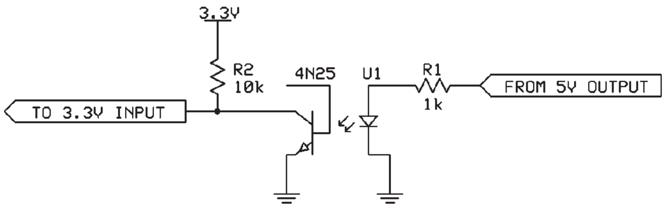


FIGURE 6. (5V/3.3V GND should NOT be common).

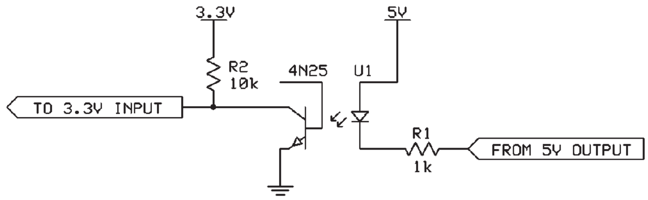


FIGURE 7.

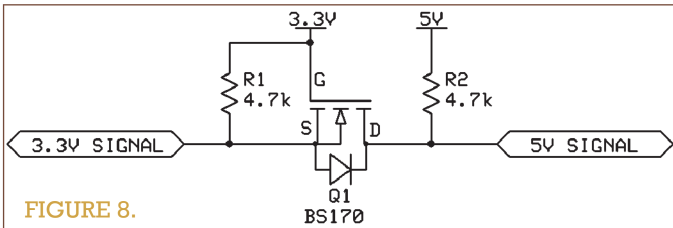


FIGURE 8.

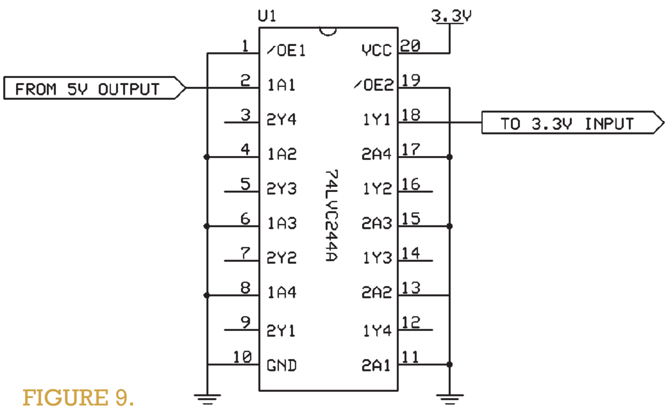


FIGURE 9.

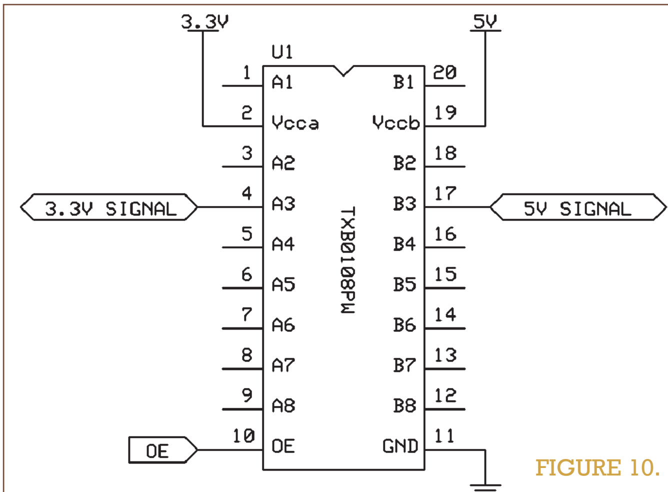


FIGURE 10.

output is concerned, but with two important benefits. First, optical isolators can provide complete electrical isolation between two different devices which can be useful if there is a lot of electrical noise present. The other benefit when using optical isolators is that it is possible to prevent the signal from being inverted, depending on how the input to the opto is wired. This is because the input to the opto is essentially an LED. This LED controls the base of the transistor, providing isolation while biasing the internal photo transistor. **Figure 6** shows how a 4N25 opto-coupler could be connected to send a 5V signal safely to a 3.3V input.

Note that this circuit still inverts the signal. However, this effect can easily be changed by connecting the input as active low rather than active high as shown in **Figure 7**.

By keeping the signals optically isolated, noise and voltage issues are non-existent. In this manner, opto-couplers have several advantages over previous methods demonstrated for interfacing 5V and 3.3V signals. Opto-couplers are also very useful for interfacing 5V or 3.3V microcontrollers to devices that operate at much higher voltages, such as 12V automotive systems or 24V industrial applications.

MOSFET (Pass Transistor) Interface

In open-collector systems such as 1-Wire®, I^2C, or even non-inverted serial interfaces, a pass transistor interface such as the one shown in **Figure 8** is an ideal method for bi-directional level translation, and can be achieved with an N-Channel MOSFET such as the BS170. If neither device (5V or 3.3V) pulls the data line low, V_{GS} of Q1 is 0V and the 5V device sees 5V while the 3.3V device remains at 3.3V.

If the 3.3V device pulls the data line low, the V_{GS} of Q1 is 3.3V and will turn on Q1, pulling the 5V data line low. If the 5V device pulls the data line low, the body diode of Q1 will be forward biased, pulling the source to 0.6V. V_{GS} will be 2.7V and Q1 will turn on, pulling the 3.3V data line low. In this manner, logic levels are translated in both directions. Ideally, the 3.3V device will have zero resistance at ground. However, in a real-world application this is likely not the case. If you factor in the resistance of the sinking driver, you can calculate that V_{GS} will not necessarily be at 3.3V but lower, depending on the value of R1 and the R_{DS} of Q1.

In this design, the slew rate is directly dependent on the values of R1/R2 and the number of devices sharing the bus which can affect capacitance. Lower resistor values will increase the maximum transmission rate, however, power consumption will be increased.

Buffer Interface

Buffer arrays are typically used to buffer current on a signal bus. However, they can be used to interface 5V devices to 3.3V devices by using a special family of buffer known as LVC (Low Voltage CMOS). This particular family is suited to 3.3V devices while providing 5V tolerant inputs. A common 74xxx buffer for interfacing 5V devices to 3.3V devices is the 74LVC244A which is an octal buffer, enabled in two groups of four ports.

The 74LVC244A provides a non-inverting 3.3V buffered output which can accept both 5V and 3.3V input signals. The outputs are capable of sourcing/sinking up to 50 mA and the supply range is typically 1.65V to 3.6V, making 1.8V operation possible. The signal is unidirectional. As you can see from **Figure 9**, the pins are grouped into two ports with four outputs each. There is a separate output enable pin for each group of pins.

When an /OE pin is high, the outputs for that group are high impedance. When an /OE pin is low, data is passed from an A input to the Y output at a level equal to V_{CC}. Unused inputs are commonly tied to ground to reduce noise and power consumption.

Voltage Translator Interface

Voltage translators are specialized devices designed to overcome traditional problems associated with bi-directional mixed voltage interfaces. As specialized devices, these voltage translators are not typically to be used in a design without verifying the electrical requirements of the circuit against those required by the translator.

The TXB0108PW is a non-inverting, bi-directional eight port voltage translator with individual V_{CCA} and V_{CCB} supply inputs and an active high output enable. Port A can operate from 1.2V to 3.6V, and port B can operate from 1.65V to 5.5V. However, the port A voltage supply must always be less than or equal to the port B voltage supply.

Devices such as the TXB0108PW implement protection features such as disabling the outputs when either Port V_{CC} is at ground. This device also contains one-shots to detect rising and falling edges on ports A and B. This speeds up low-to-high and high-to-low transitions. The TXB0108PW — like other similar devices — will have specific requirements for the input/output circuits to ensure proper operation.

For example, the TXB0108PW requires an input drive strength of at least ±2 mA. The device is also designed to drive capacitive loads of up to 70 pF. Output loads must have an impedance of >50 kΩ so as not to contend with the output drivers. This excludes the TXB0108PW from use in I[2]C or 1-Wire interfaces, or anywhere there is an open-drain driver connected to the bi-directional data line.

Conclusion

This article demonstrated many ways of interfacing 5V and 3.3V technology. With all these choices, I'm sure you'll find one to suit your particular application. **NV**

Chris Savage
chris@savagecircuits.com; www.savagecircuits.com

#33 SMILEY'S WORKSHOP

C PROGRAMMING - HARDWARE - PROJECTS

USB to UART for Electronic Prototyping — Part 1

by Joe Pardue

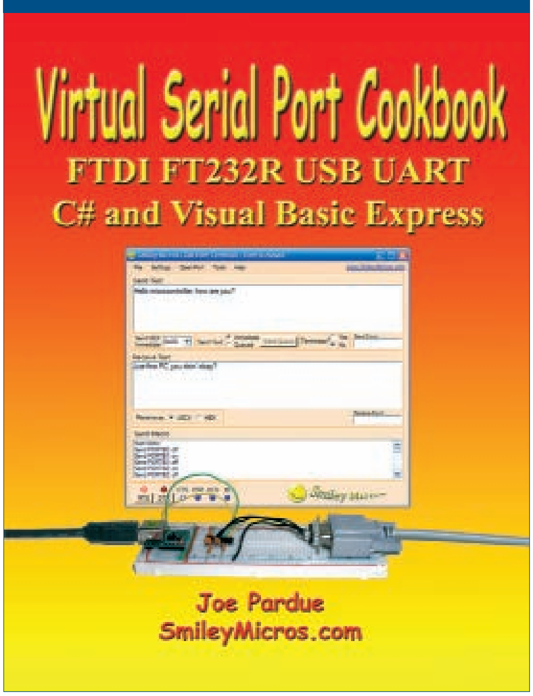
Follow along with this series! Joe's book & kits are available at www.nutsvolts.com

Recap

Last month, we finished discussing the preliminaries for the avrtoolbox open source project and said that if all goes well, we would continue with avrtoolbox by writing an elementary serial function library. And we will, but just not for the next two months. I got off on another tangent, this time based on my releasing a revision to my book *Virtual Serial Port Cookbook*. This is the first of a two-part series providing a very convenient way to hook up a serial connection between a PC and a solderless breadboard for use in electronics prototyping. My book is about the FTDI FT232R USB to UART converter that lets folks use their PC USB connection to emulate the much easier to use serial communication port that served our prototyping needs so well for so long. The book revision is mainly to incorporate two additional FT232R prototyping boards: the Gravitech board (**http://store.gravitech.us/ftusbtouabrb.html** — note this is .us NOT .com) and the Bob-00718 from SparkFun (**www.sparkfun.com/products/718**).

You may already know that the Arduino up until the most recent release used this very chip (FT232RL) for serial communications which is a testament to its ease of use. To tie this to Atmel AVRs — which is what this Workshop is supposed to be about — we'll revisit the BreadboArduino — an Arduino on a breadboard we discussed in Workshop 21 — only this time with the Gravitech board AND a kit available from *Nuts & Volts*, so that you can get all the parts in one place without having to look all over the place.

■ FIGURE 1. *Virtual Serial Port Cookbook.*



This is NOT a Shootout!

There are many really good breakout boards for the FTDI FT232R IC. I've got a bunch from various companies and I have yet to find one that didn't work as advertised. So, our goal here is not to say that any one board is better than another. As mentioned, I've chosen one from Gravitech and the other from SparkFun — both fine boards from fine companies. The project kit that goes with these articles has the Gravitech board, but the SparkFun board would do just as well (and you can follow the instructions in Workshop 21 available in my blog at **www.smileymicros.com\blog** if you want to use that board).

Both of these boards have two LEDs attached to show USB transmission and reception traffic, and while it can be a convenient debugging feature it has the downside of blocking two of the CBUS pins that could otherwise be used for general input/output or some other special features you'll learn about later. If you want to use these features, you'll have to make changes to the PCB of the 'voids warranties' and 'runs with scissors' variety that I won't provide instructions for (I get yelled at entirely too much as it is). I'll admit I do this sort of thing all the time myself (though I don't yell at the folks who sold me the board I trashed). Each of these boards provides the following:

- A Virtual COM port (imitates legacy PC serial ports).
- FTDI FT232R USB UART IC single chip USB solution.
- UART voltage levels of either 5V or 3.3V (not RS-232 voltages*).
- Easy to use, royalty-free FTDI drivers for Windows, Linux, and Mac.
  - PC Virtual COM port drivers for legacy serial communications with microcontroller UARTs.
  - Bit-bang mode using special drivers and software.
- Fourteen I/O lines for use with RS-232, bit-bang, or special function modes.
- USB bus power of 5V at up to 500 mA or regulated 3.3V at up to 50 mA.
- Unique serial number for security-dongle applications using FTDIChip-ID™.
- Clock generator to drive microcontrollers (6, 12, 24, and 48 MHz).
- LED drivers to show serial traffic.

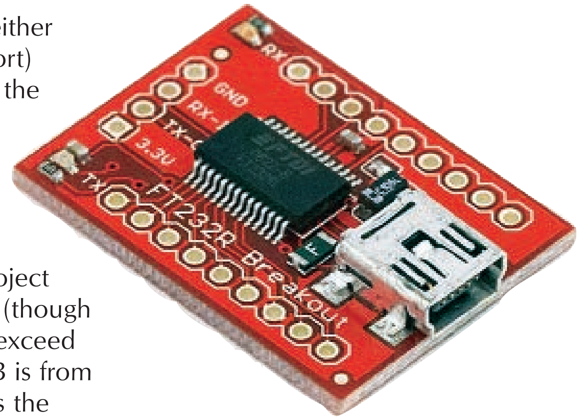
*Please note that these boards do not output RS-232 voltage levels; instead they output TTL UART voltage levels of either 5V or 3.3V which is a good thing if you are connecting directly to a microcontroller UART. One of the big problems with store-bought USB to serial port converters is that in order to use them with a microcontroller, you have to convert from the RS-232 voltage levels to the UART voltage level. However, these boards allow you to bypass that step. The book has a chapter that tells you how to use a special RS-232 voltage converter IC to turn these boards into a fully functional USB to RS-232 conversion cable.

These boards also allow you to use your PC to communicate with *and* power a breadboard electronic prototyping project. You have two choices for communicating: either use the VCP (Virtual COM port) drivers for serial ports, or use the FTDI D2XX direct drivers from a special Dynamic Link Library (DLL) to directly control access to the USB device and pin I/O. You can also provide your project with either 5V up to 500 mA (though I recommend that you don't exceed 100 mA just in case your USB is from an un-powered hub that limits the current) or 3.3V up to 50 mA from the PC USB cable. Or, you can choose to power the board and your project from your own power supply.

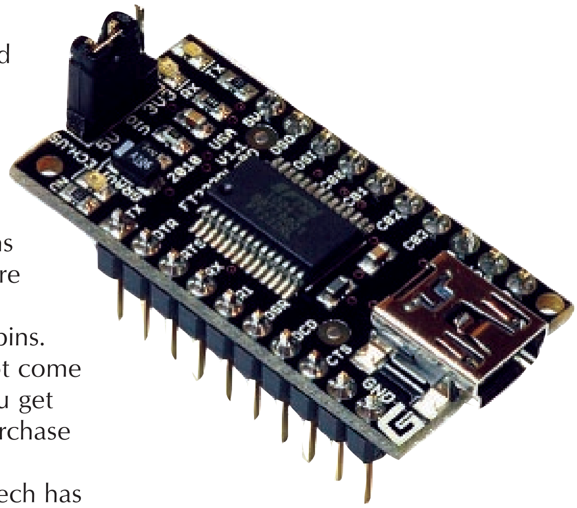
These boards can be used in any breadboard project requiring a drop-in serial communications module, since they have standard .1" pin spacing and use gold-plated square header pins that are longer and much more sturdy than usual IC pins or ordinary 'Stamp' type board pins. (The SparkFun board does not come with the header pins, so if you get their board, you'll need to purchase the legs separately.)

As of this printing, Gravitech has the best price for one of these boards that I know about which is $12.99 for item #FT232RL-BO (**Figure 2**).

The BOB-00718 (**Figure 3**) from SparkFun was $14.95 in February '10. Remember to purchase the legs separately.



■ FIGURE 3. SparkFun board BOB-00718.

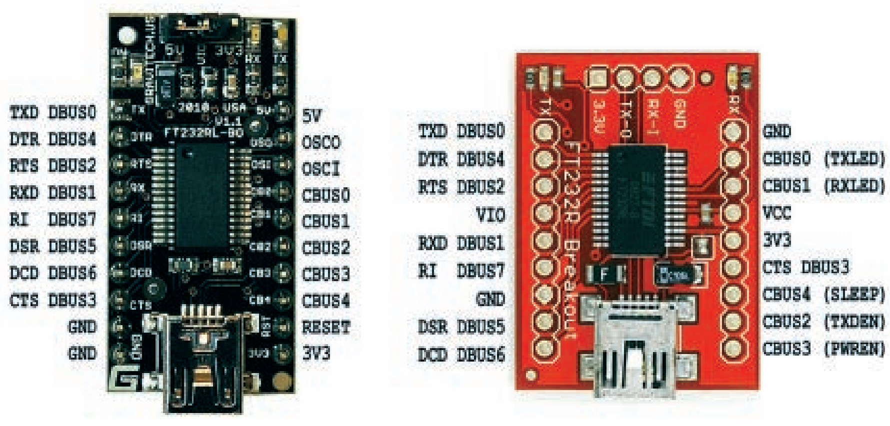


■ FIGURE 2. Gravitech board FT232RL-BO.

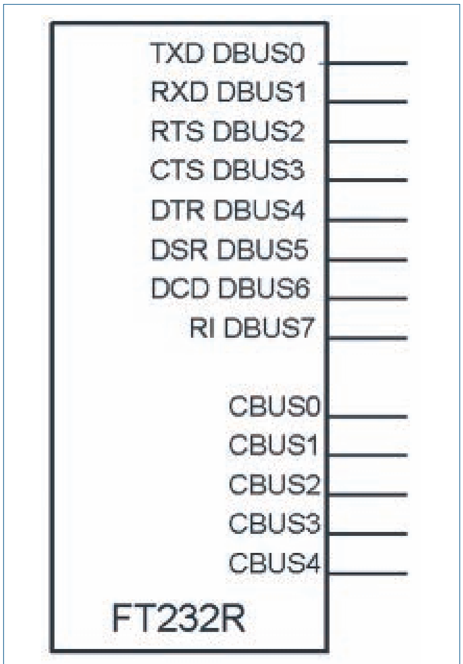
Why the Heck Imitate a PC Serial Port with USB?

In the olden days, the PC serial port had a Windows software serial port driver and hardware link based on the RS-232 electrical specification, and used a DB-9 connector and a UART (Universal Asynchronous Receiver Transmitter). It wasn't exactly simple for a novice PC user to hook up a serial link since it required the user to select software interrupts and set hardware jumpers — something you and I as certifiable geeks like to do, but something that normal people hate and tend to screw up. These and other complications led to the development of the Plug and Play initiative (more commonly and correctly known as Plug and Pray). One part of all this was to replace the serial port with USB to help simplify things which it did for the casual user, but made the developer's life (yours and mine) much more complicated. USB also obsoletes lots of perfectly good serial devices and a couple of decades of knowledge of how to do robust RS-232 style serial communications between PCs and external serial devices.

I've read the USB specification, and I'm here to testify (brother, amen) that the old COMPORT/UART/RS-232 was a piece of cake compared to USB. I



■ FIGURE 4. Board pin-outs.

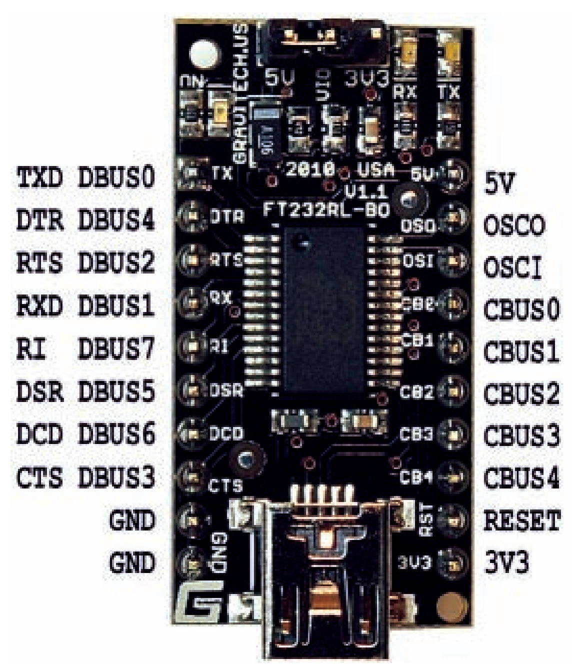


■ FIGURE 5. FT232R schematic symbol.

worked with USB when it first came out and my brain is worse for the wear. Fortunately, some geniuses thought that they would simplify the life of not just the user but the developer too by creating a transitional concept, that is, to have an old fashioned RS-232 style serial port that runs over USB. The FTDI folks call this a Virtual Communications Port (VCP). It allows legacy applications to continue to use the old microcontroller code and the Windows serial port software with the USB part, all tidily bound up in a black box that the developer doesn't have to open. These transitional devices give us the best of both worlds: the ease of using the serial port and the ubiquity of using USB. The developer has the option of adding RS-232 level converts to completely emulate the old way of doing things, or leaving the level converters off and outputting voltage levels directly compatible with a microcontroller's UART.

The FTDI solution to this problem is to dedicate a microcontroller to accept USB data and translate it into UART type data. They also have learned along the way that this 'dedicated' microcontroller can also have some features that aren't really part of either USB or UART. For example, the FT232R has pins that can be used to twiddle transmission indicator LEDs, bit-bang I/O (Input/Output), contain a unique serial number (security dongle anyone?), or even provide a clock and power for another microcontroller. All this adds not only to easing the job of communication between the PC and an external serial device, it also adds complexity that can at times be quite, well, complex. We'll address some of the complexity in next month's Workshop column.

■ FIGURE 6. Labeled Gravitech board pins.



FT232R Quick Start Guide

This section will help you to get started with the breakout board you've chosen to use for the *Virtual Serial Port Cookbook* (2011 revision) projects. We will begin with the Gravitech board and follow with the SparkFun board. Each of these boards installs the same way on the PC and each uses USB software the same, so the last section will cover installation and use with a terminal program as a generic discussion.

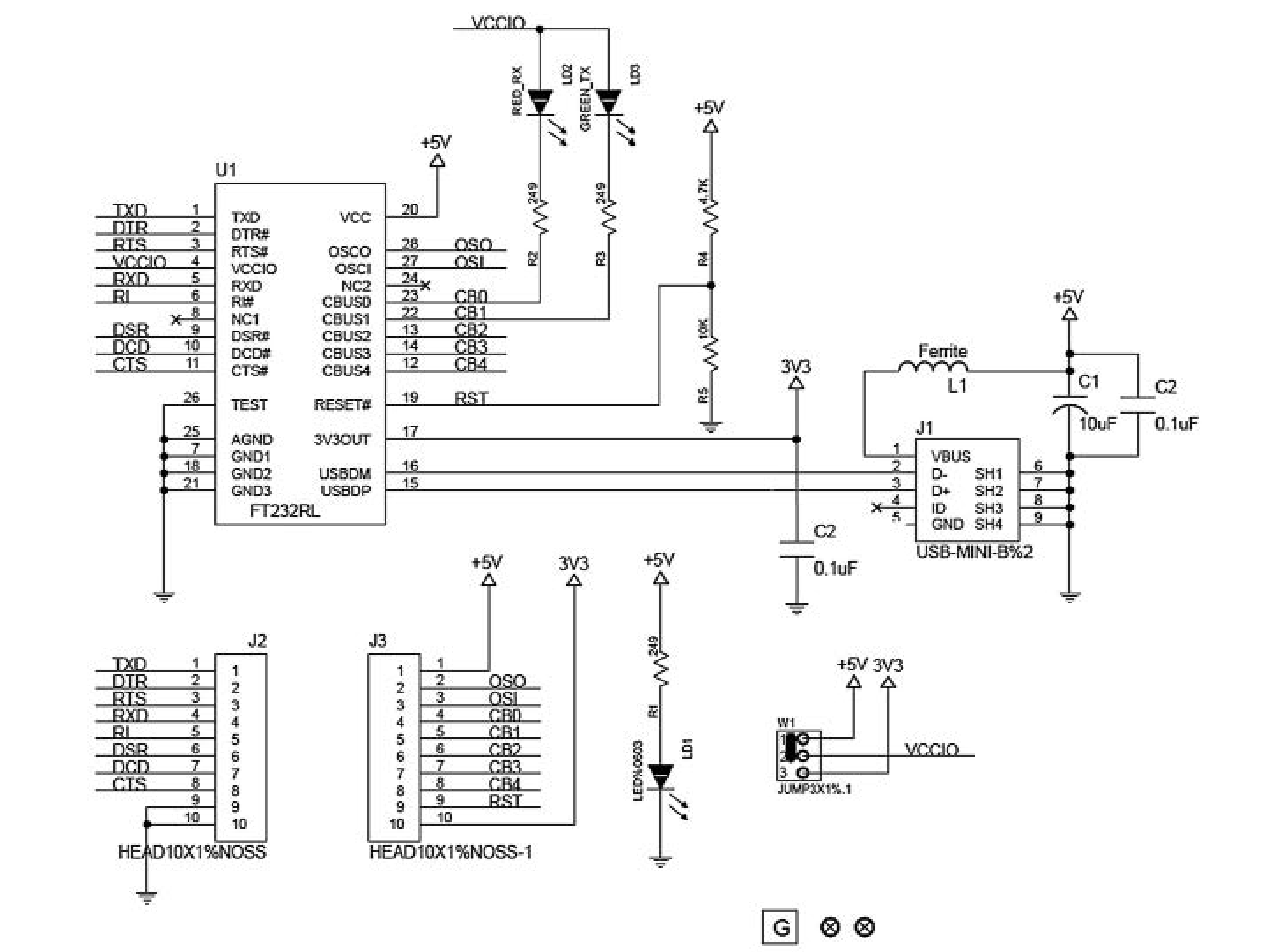
■ FIGURE 7. Gravitech board hat.

gravitech

D0-TXD	5V
D4-DTR	OSCO
D2-RTS	OSCI
D1-RXD	C0
D7-RI	C1
D5-DSR	C2
D6-DCD	C3
D3-CTS	C4
GND	RESET
GND	3V3

How the Boards Differ

Each of these boards differs in some respects from the others. They will all function perfectly well for our hardware and software demonstrations. However, since the pin-outs are different, the wiring on the



■ FIGURE 8. Gravitech board schematic.

breadboard hardware experiments will be different.

Pin-outs:

Each board has a different pin-out that will be shown shortly. The hardware demonstrations use a generic FT232R component that does not show either the actual PCB pin-outs or the power pins for any of the boards. The user will be expected to learn in this section how the schematic symbol actually maps to the real board and then in later sections apply that knowledge to the experiments shown.

Size:

Each of the boards differs slightly in size.

Connectors:

Both boards use the small MiniB connectors, so you will need the appropriate USB cable.

Power:

The Gravitech board can be configured for either five or 3.3 volts; the SparkFun board only works at 3.3 volts (refer to their website to convert it to five volts). The pin location for voltage and ground varies between each device and is not shown in the hardware demonstration schematic. Users should read the section on setting up their device and then preset the power before doing the hardware demonstrations.

LEDs:

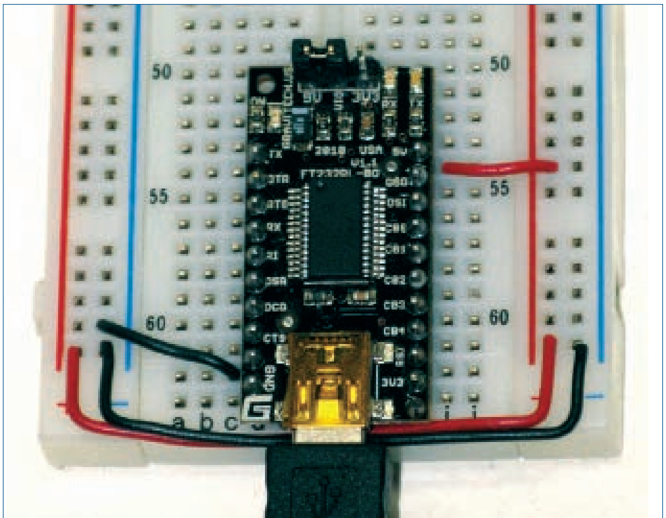
Both the SparkFun and the Gravitech boards have LEDs to indicate TX and RX. The TX and RX indicators are taken off two of the CBUS pins and must be considered in circuits that use these pins for other applications.

OSC:

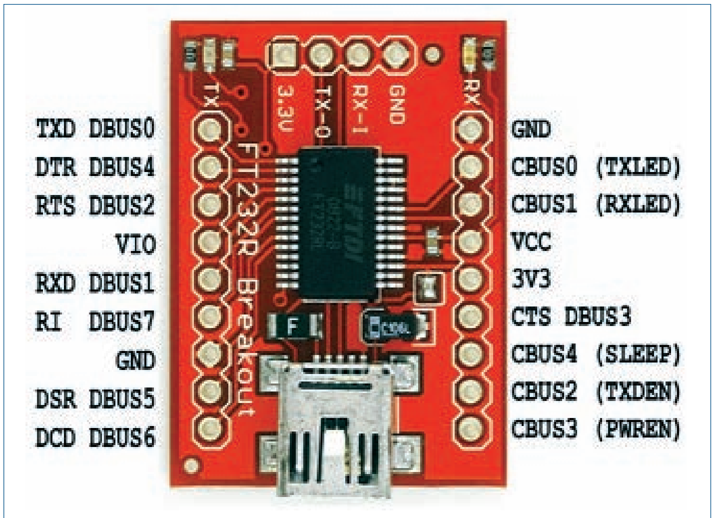
The Gravitech board has two OSC pins that we will not consider in this article.

Generic Schematic Symbol Versus the Actual Boards

Each of our three boards is wired up differently, so we will use a single generic schematic symbol for our hardware demonstrations that will show only the common pins used by each board. In the following sections, you will see how to set up your particular board and you will test your setup with a simple loop-back test (you send a character and the FT232R sends it back to you). For subsequent demonstrations, you may need to refer back to this section to



■ FIGURE 9. Gravitech board wired for USB bus 3.3V.



■ FIGURE 10. Labeled SparkFun board pins.

understand the actual breadboard layouts.

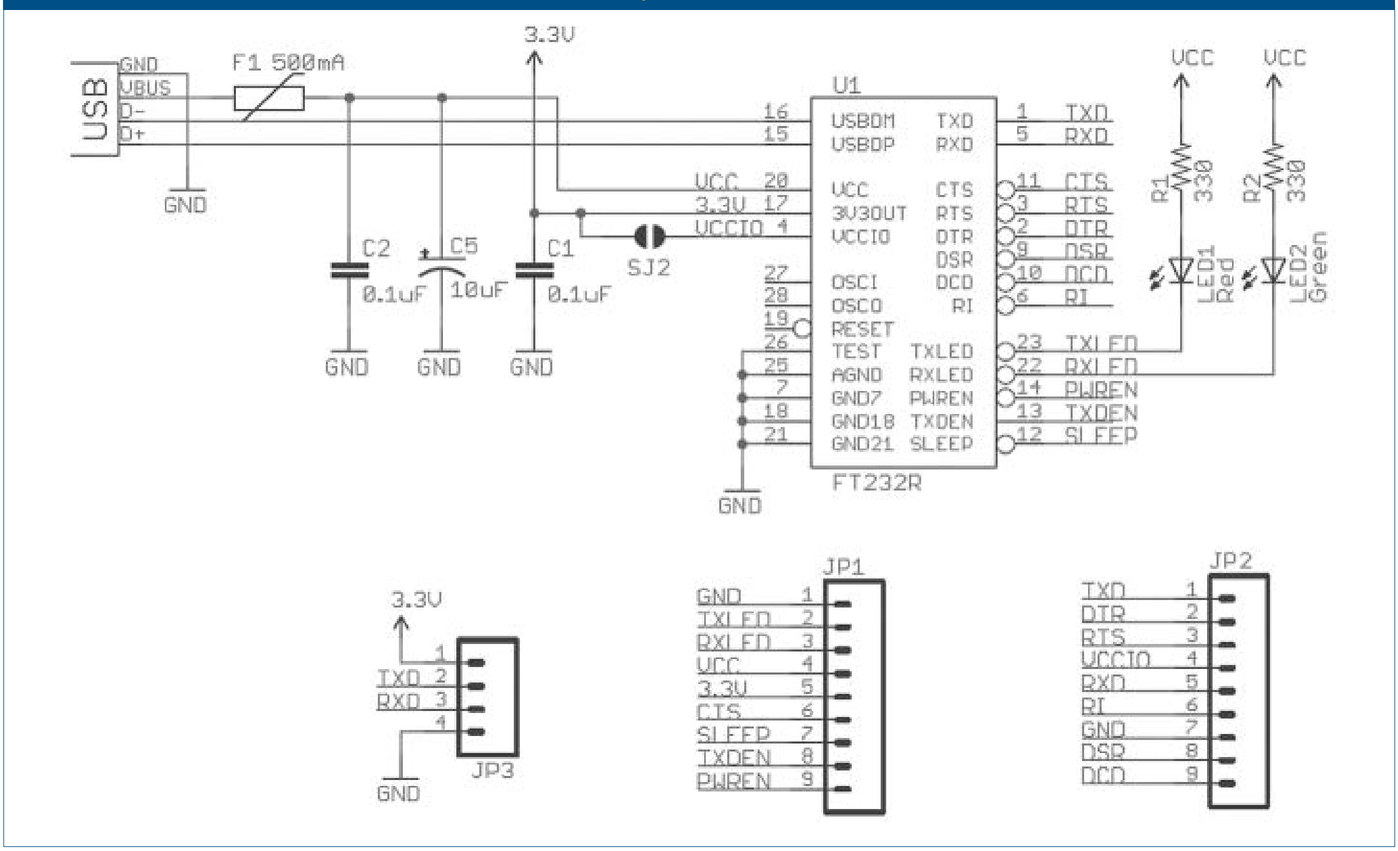
Power

The USB bus can provide up to 500 mA power to a USB device, but certain rules must be followed. Violating the rules can result in your PC assuming a USB bus power fault, and the PC may then shut down (no warning, just a black screen and bye-bye to all your unsaved work — this is not an official 'fact' but a personal observation). Save your work frequently when playing with these devices and be prepared to reboot your system.

The USB peripheral tells the USB host how much power it needs in 100 mA units up to 500 mA. It cannot use more than 100 mA while starting up before making a request for more power. The USB host can deny the peripheral's request for more power. Also, if the USB host tells the peripheral to go into suspend mode, it must not use more than 500 µA. This can get complex.

For instance, a device off a bus-powered hub cannot use more than 100 mA, but you can have hubs with external power that can supply the full 500 mA. For the quick start guide, we will assume

■ FIGURE 11. SparkFun board schematic.

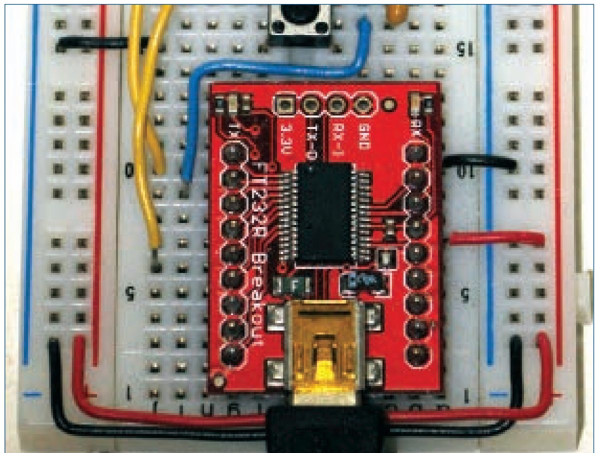


that the device is powered either directly from a PC or from an externally powered hub so that we can use up to 500 mA. Don't forget if you use the 3.3V from the FT232R, you are limited to 50 mA.

sparkfun

C3-PWRN	DCD-D6
C2-TXDEN	DSR-D5
C4-SLEEP	GND
D3-CTS	RI-D7
V3.3	RXD-D1
VCC	VCCIO
C1-RXLED	RTS-D2
C0-TXLED	DTR-D4
GND	TXD-D0

■ FIGURE 12. SparkFun board hat.



■ FIGURE 13. SparkFun board wired for USB bus 5V.

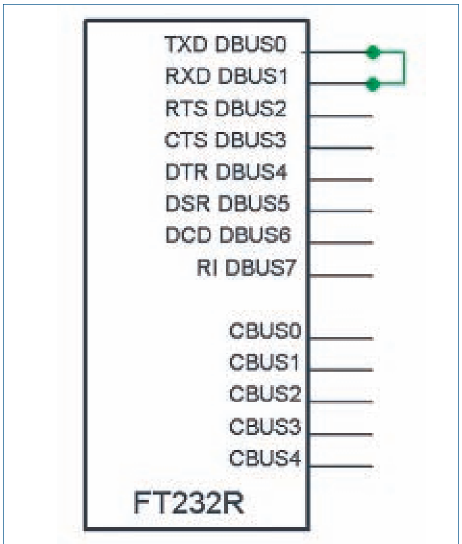
Setting Up the Gravitech Board

Layout and Schematic:

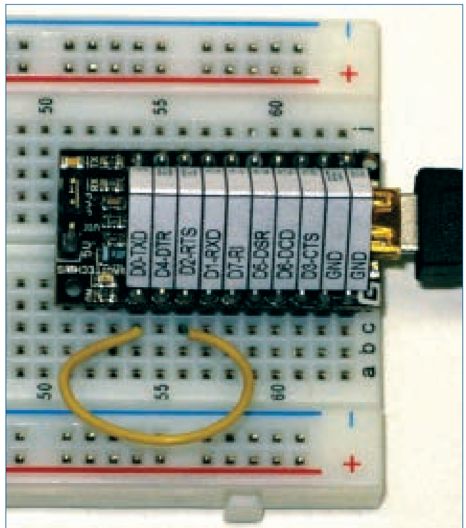
You can find a printable version of the Gravitech board hat shown in **Figure 7** on the book webpage at **www.smileymicros.com** or **www.nutsvolts.com**.

Power Wiring:

Select either five or 3.3 volts from the jumper and take the board power from the selected pin.



■ FIGURE 14. Loop-back schematic.



■ FIGURE 15. Gravitech wearing the pin-out hat for the loop-back test.

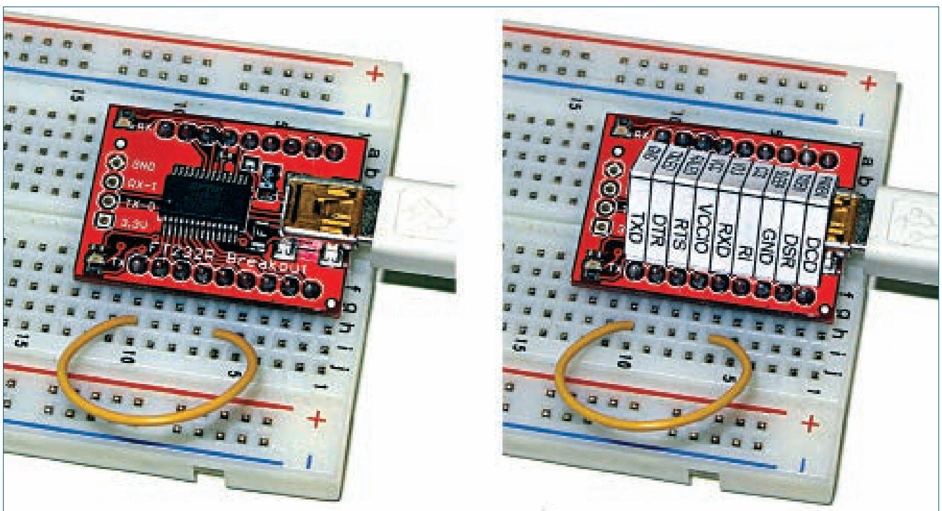
Setting Up the SparkFun Board

Layout and Schematic:

You can find a printable version of the SparkFun board hat shown in **Figure 12** at the same websites mentioned previously.

Power Wiring:

The SparkFun board is wired for 3.3 volts but can be converted to five volts – visit their website to see how to do this.



■ FIGURE 16. SparkFun board loop-back test with and without hat on.

Loop-back Test

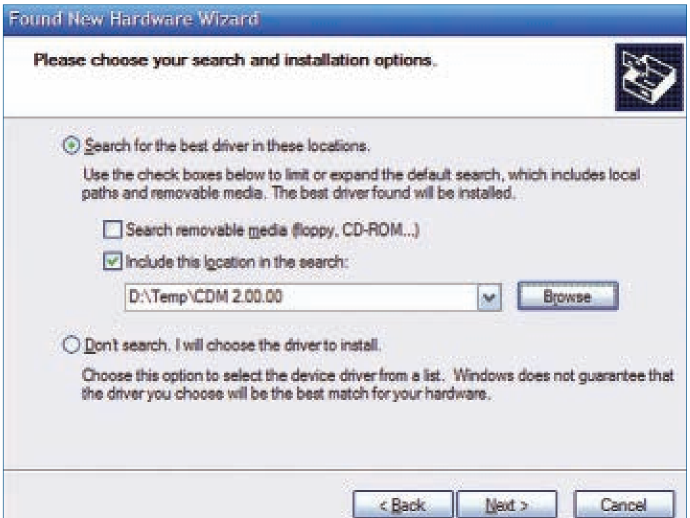
The loop-back test couldn't be simpler. Just run a wire from the transmission pin TxD to the reception pin RxD, and whatever you send out on the port will be sent back to you. This is an excellent test to make sure everything is working properly. You may well remember this test later when you get a bunch of stuff on a breadboard and something isn't working right. This test will eliminate the terminal program, the wire between the PC and the FT232R board, and the board itself as culprits.

Installation and Use With a Terminal Program

- Plug a USB cable into your PC and the BBUSB.
- If you are using XP, the window in **Figure 17** will appear.
- Windows wants to waste a

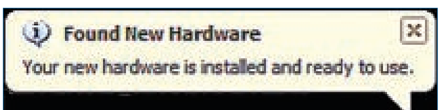
■ FIGURE 17. Found New Hardware Wizard 1.

■ FIGURE 18. Found New Hardware Wizard 2.

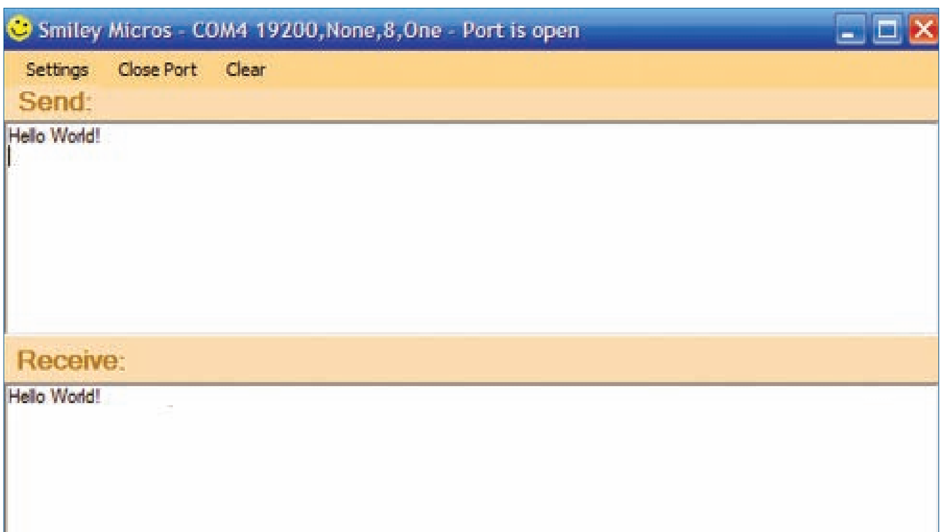


■ FIGURE 19. Found New Hardware Wizard 3.

■ FIGURE 20. Found New Hardware Wizard 4.



■ FIGURE 21. Found New Hardware Wizard 5.



■ FIGURE 22. Simple Terminal Hello World!

bunch of your time searching for something it won't find and asks for permission. Click the 'No, not this time' radio button. Actually, I'd prefer a less polite 'Heck NO! Not now, not never!!!' option, but it isn't available. Click the 'Next' button and the window in **Figure 18** will appear.

- Select the 'Install from a list or specific location (Advanced) radio button, then click the 'Next' button and the window in **Figure 19** will appear.
- Click the 'Browse' button and locate the CDM 2.00.00 directory which contains the FTDI drivers. You can find the FTDI software used in this book in the *Nuts & Volts* downloads section, or the

newest version at **www.ftdichip.com**. Click the ‘Next’ button and the window in **Figure 20** will appear.

- Click Finish and the balloon in **Figure 21** will pop up.
- Don’t be shocked to see that the very first Windows Form in the above sequence pops up again. Rather than waste the space showing all the above forms again, just note that two sets of drivers are installed and this second round will proceed exactly as above.

The Simple Terminal Software

Back in the January and February ‘10 issues of *Nuts & Volts*, we had workshops on writing a Simple Terminal program using C# .NET. To install this terminal, follow these steps:

- You do have .NET Framework installed, don’t you? You will find out as soon as you try to open Simple Terminal (located in the downloads section) in the next step. If Simple Terminal opens, then you have .NET; if it doesn’t, then get it on the Microsoft website.
- Open Simple Terminal by clicking on SimpleTerm.exe.
- Make sure your FT232R board is plugged into your PC and set up for the loop-back test discussed previously.
- Open the Settings menu item and select the COM port for your FT232R
- Type in ‘Hello World!” and you should receive ‘Hello World!’ as shown in **Figure 22**.

Vitual Serial Port Cookbook Revision **and kit to go with these series of articles can be purchased online from the *Nuts & Volts* Webstore www.nutsvolts.com or call our order desk at 800-783-4624.**

That’s all for the first part of this two-part series. Next month, we look at using the FT232R modem lines, then using it for general-purpose input/output to read switches and light LEDs. Then, we will use a seven-segment LED to make the “World’s Smallest Moving Message Sign.” Finally, we will revisit the BreadboArduino. **NV**

■ BY FRED EADY

DRIVE YOUR PROJECTS WITH THE SPECTRUM ACE ECS

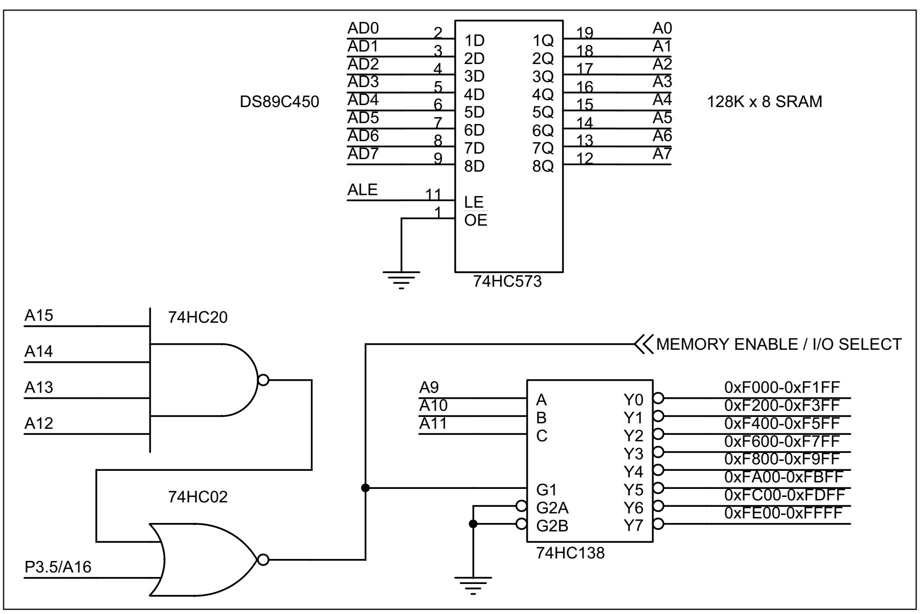
Automobiles and things automobile are often used to make a point about non-automobile subjects. For instance, running an application with the I2I Controls SPECTRUM Lite Single Board Computer is like driving a 1960's era muscle car. You can't put a bunch of folks in it, but it has a really big motor and runs like a scalded dog.

The I2I Controls SPECTRUM ACE 2a is the largest computing vehicle in the SPECTRUM ACE family of microcontroller boards and is based on the same high performance 8051 engine that powers the SPECTRUM LITE. In automobile terms, the SPECTRUM ACE 2a is a high powered touring sedan capable of quickly transporting a number of passengers in style and elegance.

THE SPECTRUM ACE 2A

The SPECTRUM ACE 2a is based on the same basic chassis as the SPECTRUM LITE we discussed last month. However, instead of depending on raw horsepower to run an application, the ACE 2a combines the compute power of the DS89C450 microcontroller with an extensible I/O subsystem.

To understand how the ACE 2a's I/O mechanism works, let's examine the contents of **Schematic 1**. The DS89C450 microcontroller's lower address lines and data bus are handled with a 74HC573 latch exactly like they are with the LITE. However, note that the ACE 2a has 128K x 8 of SRAM compared to the SPECTRUM LITE's 32K x 8 of SRAM. The ACE 2a's 128K of SRAM can only be accessed when any combination of address lines A12 through A15 are logically low. All of the 74HC20 inputs must be logically high, along with a logically low A16 to enable the 74HC138 multiplexer output. Address line A16 is really DS89C450 microcontroller I/O pin P3.5 and is connected to the SRAM, as well as the 74HC138 active-high enable pin. When the 74HC138 mux is active, the DS89C450's I/O memory area is represented as eight 512 byte blocks which are selected by the 74HC138 outputs Y0-Y7. As you can see in **Figure 1**, only the Y0-Y6 I/O selects are pulled out for user access. I/O



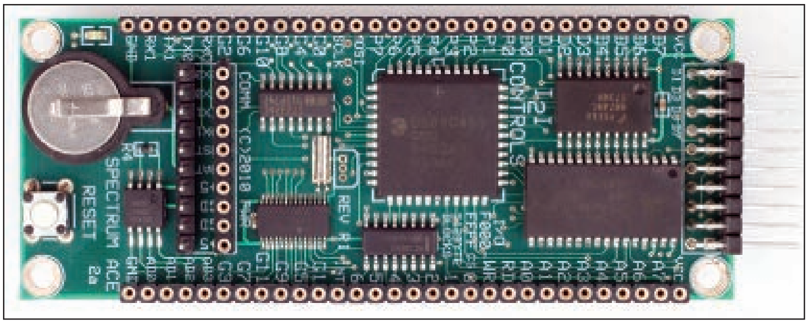
■ SCHEMATIC 1. The 74HC573 transparent octal latch is standard across the SPECTRUM ACE line. The addition of a 74HC138 multiplexer and address line decoding circuitry reveal a number of 512-byte memory-mapped I/O blocks to the SPECTRUM ACE 2a user.

select Y7 is reserved for the SPECTRUM ACE 2a's on-board battery-backed RTCC.

Photo 1 is a low level reconnaissance shot of my ACE 2a. The RTCC backup battery can be seen just above and to the left of the Dallas Semiconductor 1wire DS2450 Quad A/D Converter. You can make out the analog-to-digital converter (ADC) access points in **Photo 1**, as well as **Figure 1**.

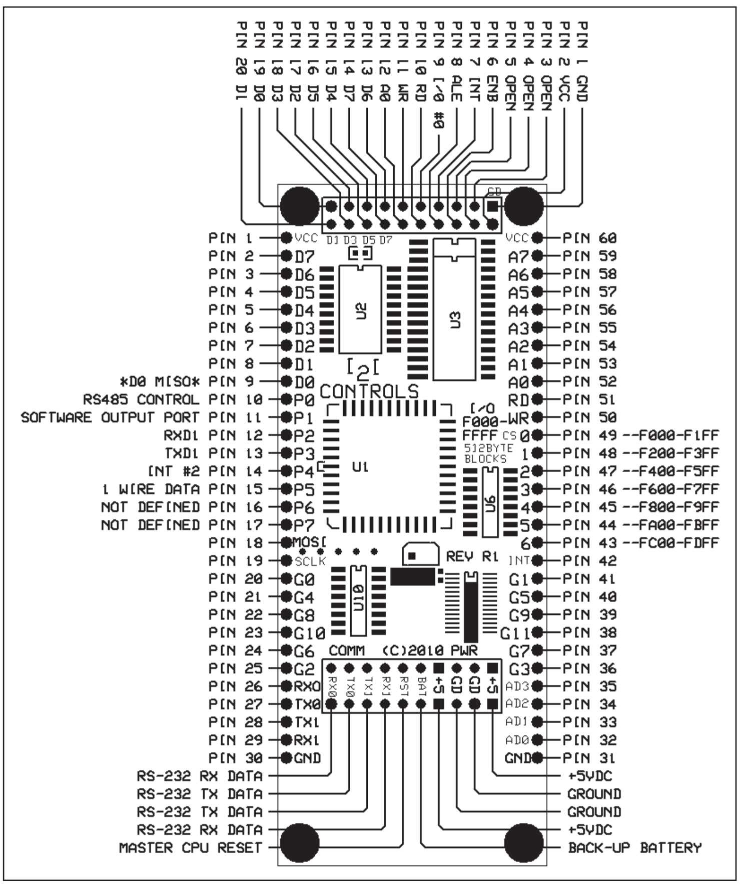
The first IC directly to the right of the DS2450 is the DS28DG02 RTCC. Hopping over the RTCC crystal, we land on the ST232 RS-232 interface IC. The big boy in the 44-pin PLCC package is the DS89C450, microcontroller. The 74HC138 multiplexer lies below the DS89C450, conveniently close to its Y0-Y6 I/O select outputs. The core 74HC573 latch and 128K x 8 SRAM stand between the DS89C450 and the 20-pin I/O header. The 74HC20 and 74HC02 are mounted on the opposite side of the printed circuit board (PCB), along with a 74HC245 bi-directional buffer/driver. The 74HC245 buffers the data bus that is pinned out at the 20-pin connector. The DS89C450's CPU clock crystal can also be found on the opposite side of the PCB under the DS89C450 microcontroller.

The SPECTRUM ACE 2a is a formidable embedded computing platform. If you're like me, that initial hardware hook-up is the only "work" sitting between the learning curve and mastering a system's hardware and firmware functions. To take the pain out of learning and developing with your ACE microcontroller board, you can plug your selected board into an ACE-friendly set of pins — otherwise known as the SPECTRUM ACE Evaluation Board. The only module that is missing from my ACE setup you see in **Photo 2** is the 12-bit analog-to-digital module that stacks on the ACE 2a. You should immediately recognize the SPECTRUM LITE and SPECTRUM ACE 2a. However, there are a couple of modules mounted on my evaluation board that you have yet to meet.



■ PHOTO 1. This is the high-end touring sedan of the SPECTRUM ACE microcontroller board family. The SPECTRUM ACE 2a is built around 128K x 8 of SRAM and includes a quad ADC and battery-backed RTCC.

■ FIGURE 1. So many pins, so little time. The Gx lines emanate from the RTCC and there are enough address, data, and control lines pulled out to the 20-pin header to drive external peripherals such as LCDs.

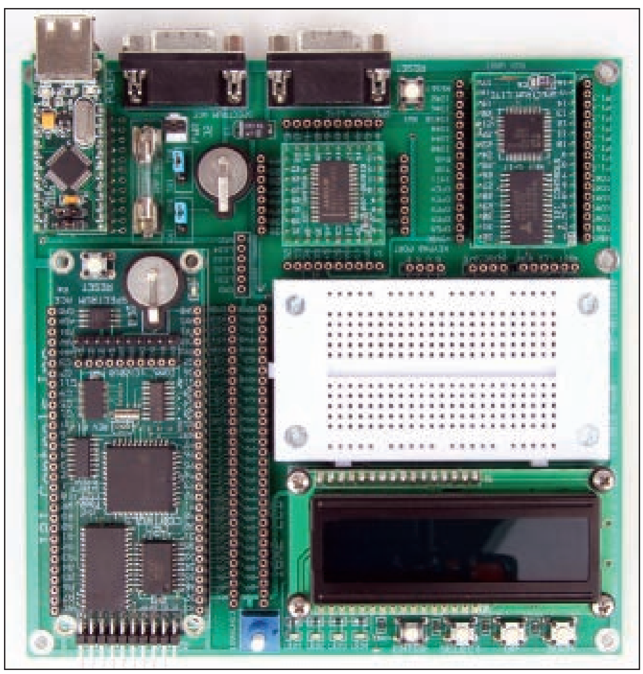


YOU'VE GOT TO BE KIDDING

How can we squeeze any more I/O capability out of the SPECTRUM ACE 2a? Easy. Populate the evaluation board's MAX7301 I/O Expander socket with a GPIO peripheral module like the one you see in **Photo 3**.

The MAX7301 I/O expander is a serial-interfaced

■ PHOTO 2. Now you know where I got that 2 x 20 red LCD you saw in last month's SPECTRUM LITE discussion. The SPECTRUM ACE evaluation board is well thought out and supports all of the SPECTRUM ACE variants and peripherals.



(SPI) I/O expander that can be used to add an additional 28 I/O pins to the ACE 1a and 2a microcontroller boards. An ACE 1a is a scaled down ACE 2a. The ACE 1a microcontroller boards are designed to act as core engines for applications that are built around a motherboard that depends heavily upon the resources of daughterboards.

Each MAX7301 I/O expander port can be individually configured as a Schmitt input with optional pullup, or as a sink/source push-pull output. The maximum current a MAX7301 GPIO output port can sink is 10 mA versus a GPIO output port source current ceiling of 4.5 mA. In addition to general-purpose I/O functions, seven of the MAX7301 ports can be assigned to interrupt on change duty.

If a module has pin real estate reserved on the evaluation board, you can bet your paycheck that ALEC supports it. Remember from last month that ALEC is the advanced on-board operating system programmed into the CPUs. With that, I'm going to relate everything you need to know to use the MAX7301 in just a few words.

Before we can communicate with the I/O expander, we must establish the MAX7301's I/O address. This is done via ALEC by issuing the SETIO,Addr instruction with the appropriate I/O address as the instruction's argument. The memory mapped address for the MAX7301 is defined in **Figure 3**. Thus, to establish the memory mapped I/O address for the I/O expander, we execute this instruction:

```
SETIO P,0xFC00;Establish the MAX7301 I/O Address
```

The "P" denotes that the memory-mapped I/O address to be established belongs to the MAX7301 I/O expander. Now we can issue instructions and commands to it.

In our imaginary application, the I/O expander needs to have its GPIO ports P4, P5, P6, and P7 act as outputs. At this point, we are not concerned with input transition detection. That means we can simply write a 0x00 (shutdown) or 0x01 (normal operation) byte to the MAX7301's Configuration Register which (according to the datasheet) is located at address 0x04. ALEC supports the PIO(register) hardware operator which is used to communicate with the expander in both program and console modes.

To begin our configuration of the MAX7301 GPIO ports, we must first shut down the MAX7301. We have already fulfilled the prerequisite of establishing the I/O expander's memory-mapped I/O address. So, we can shut down the expander like this:

```
PIO(4) = 0    ;Shutdown the MAX7301 for
              ;configuration
```

Now we can apply the expander configuration information provided in **Figure 2**. To configure our selected MAX7301 GPIO ports as outputs, we must write a binary sequence of 0b01 to each bit pair at address 0x09. If we lay down the binary bit pattern for examination, it will result in:

```
0b01010101 or 0x55
```

To load our desired port configuration value, we again turn to ALEC's PIO operator:

```
PIO(0x09) = 0x55
```

That's all it takes. The MAX7301 ports P4-P7 are now configured as GPIO output pins. At this point, we can return the MAX7301 I/O expander to normal operation by writing a logical 1 to the configuration register at address 0x04. The shutdown/normal operation bit is the least significant bit of the configuration register:

```
PIO(4) = 1    ;Return the MAX7301 to Normal
              ;Operation
```

The MAX7301 I/O expander layout (according to the ACE evaluation board) is depicted in **Figure 4**. Consulting the MAX7301 datasheet, we find that the command address for I/O 4 (P4) is 0x24. With that, let's write a logical 1 to I/O 4 using the ALEC PIO operator:

```
PIO(0x24) = 1
```

The process of writing a logical zero to I/O 4 is obvious to the most

■ FIGURE 2. If you need more detail, I suggest scouring the MAX7301 datasheet. ALEC's support for the MAX7301 I/O expander allows you to use the MAX7301 with only a minimal knowledge of how to program its internal registers.

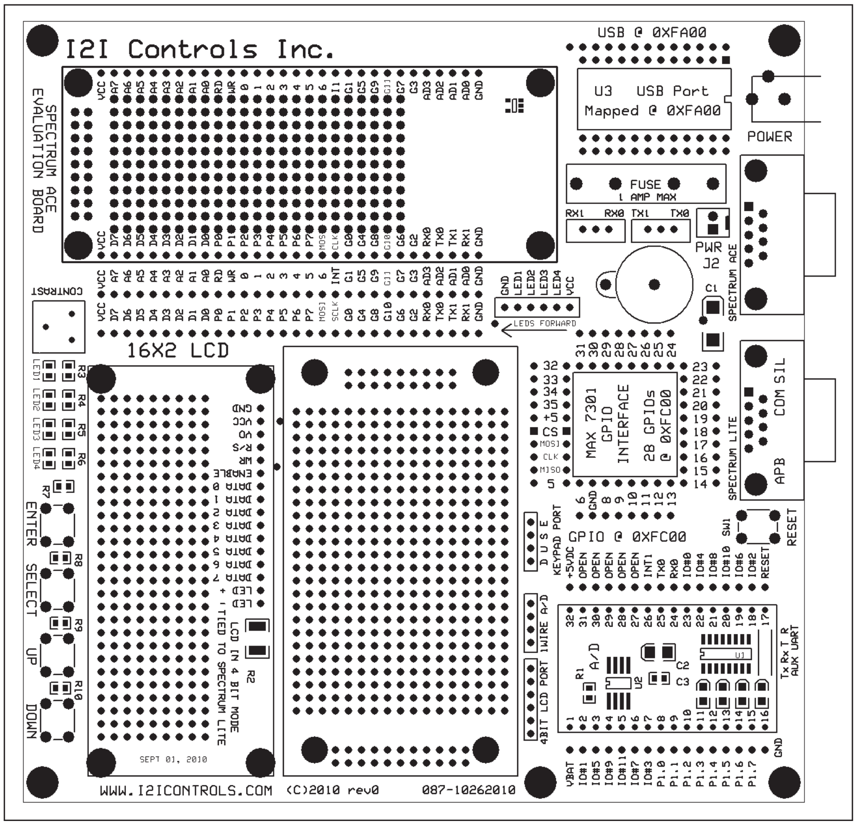
Table 1. Port Configuration Map

REGISTER	ADDRESS CODE (HEX)	REGISTER DATA							
		D7	D6	D5	D4	D3	D2	D1	D0
Port Configuration for P7, P6, P5, P4	0x09	P7		P6		P5		P4	
Port Configuration for P11, P10, P9, P8	0x0A	P11		P10		P9		P8	
Port Configuration for P15, P14, P13, P12	0x0B	P15		P14		P13		P12	
Port Configuration for P19, P18, P17, P16	0x0C	P19		P18		P17		P16	
Port Configuration for P23, P22, P21, P20	0x0D	P23		P22		P21		P20	
Port Configuration for P27, P26, P25, P24	0x0E	P27		P26		P25		P24	
Port Configuration for P31, P30, P29, P28	0x0F	P31		P30		P29		P28	

Table 2. Port Configuration Matrix

MODE	FUNCTION	PORT REGISTER (0x20–0x5F) (0xA0–0xDF)	PIN BEHAVIOR	ADDRESS CODE (HEX)	PORT CONFIGURATION BIT PAIR	
					UPPER	LOWER
DO NOT USE THIS SETTING				0x09 to 0x0F	0	0
Output	GPIO Output	Register bit = 0	Active-low logic output	0x09 to 0x0F	0	1
		Register bit = 1	Active-high logic output			
Input	GPIO Input Without Pullup	Register bit = input logic level	Schmitt logic input	0x09 to 0x0F	1	0
Input	GPIO Input with Pullup		Schmitt logic input with pullup	0x09 to 0x0F	1	1

■ PHOTO 3. This little bugger can be a handful to code for unless you have the power of ALEC behind you.



■ FIGURE 3. The memory-mapped I/O addresses for the SPECTRUM ACE evaluation board are listed in this graphic. Some that you don't see include the MAX197 12-bit ADC board which is mapped at 0xF200.

casual observer. As I mentioned earlier, ALEC's PIO operator can be used in console mode, as well as program mode. That means we can take all of the PIO console entries we just generated and form them up into a program.

Let's assemble an ALEC program that alternately sets and resets every MAX7301 GPIO pin. Our expander program will shutdown the MAX7301, assign all GPIO pins as outputs, return the MAX7301 to normal operation, and alternately write a logical zero and logical 1 to every GPIO pin. Here we go:

```
1 ;TRACE S
10 GOSUB 1000
20 FOR x=0x24 to 0x3F
30 PIO(x)=0 : p.x,
40 NEXT x
50 FOR x=0x24 to 0x3F
60 PIO(x)=1 : p.x,
70 NEXT x
80 J.20
1000 SETIO P, 0xFC00
1010 PIO(0x04)=0 : FOR x=0x09 to 0x0F
: PIO(x)=0x55 : NEXT x
1020 PIO(0x04)=1
1030 RETURN
```

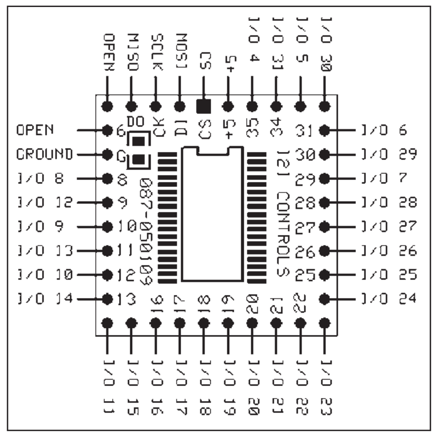
This exercise program is very easy to follow. The subroutine at line 1000 establishes the expander memory-mapped I/O address and configures the GPIO port directions. Note that we're configuring all of the available GPIO ports in the subroutine FOR-NEXT loop. We're also writing to every GPIO port beginning with I/O 4 at command address 0x24, and ending with I/O 31 at command address 0x3F. I included a single step trace option in line 1. Removing the comment operator preceding the TRACE S instruction would force the program to single-step with every key press. The p.x instruction serves two purposes. The "p." is ALEC shorthand for PRINT and the time it takes to print the current value of the variable "x" to the console forces a small time delay between the GPIO port logic transitions. Driving an LED with any MAX7301 GPIO pin will result in a blinking LED.

Mastering the MAX7301 I/O expander input functionality is just as important as being a MAX7301 GPIO output wizard. Thanks to the GPIO output discussion, we have all of the knowledge necessary to write an ALEC program that reads a specific MAX7301 input port and passes the captured input logic level to a predetermined MAX7301 GPIO output port. We'll configure I/O 4 as a Schmitt GPIO input with pullup, and I/O 5 as a GPIO output. MAX7301 I/O ports P6 and P7 are to be configured as "don't care" inputs. Here's that bit I/O port pattern according to the rules set forth in **Figure 2**:

```
0b10100111 = 0xA7
```

Parsing the binary port configuration register byte tells

■ FIGURE 4. Don't try to match up these GPIO port pins with the MAX7301 I/O expander datasheet. They don't match. For instance, I/O 4 is not located on pin 35 of the MAX7301.

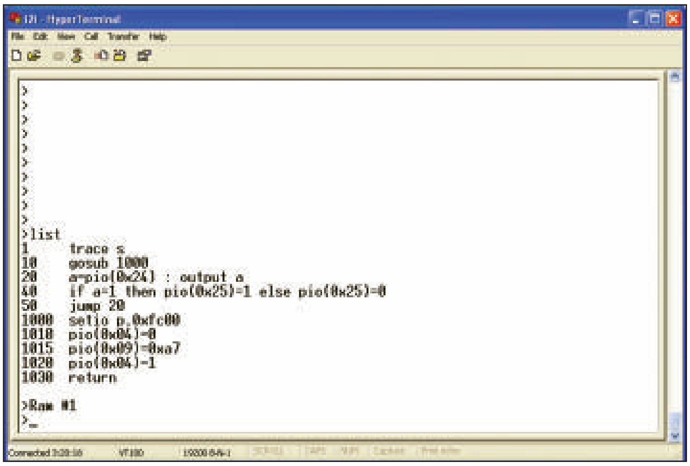


us that I/O 4 (P4) is now a Schmitt input with pullup (0b11). I/O 5 (P5) is a GPIO output (0b01), and I/O ports P6 (I/O 6) and P7 (I/O 7) are Schmitt inputs sans pullups (0b10). Like the GPIO output exercise program, the actual configuration work will be done in a subroutine. The rest of the logic is really straightforward:

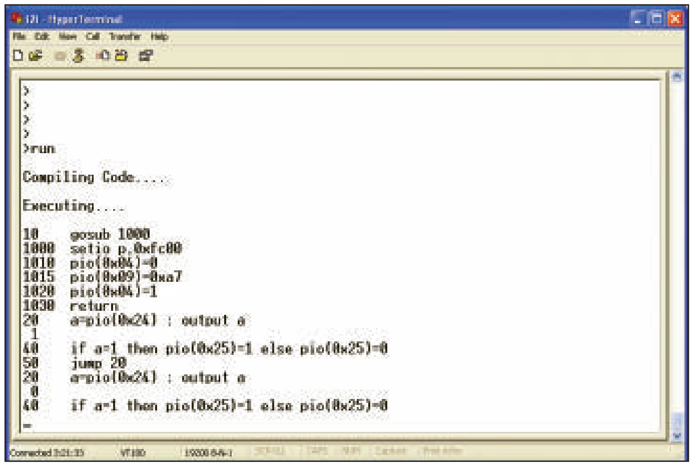
```
1 TRACE S
10 GOSUB 1000
20 a = PIO(0x24) : p.a
40 IF a=1 THEN PIO(0x25)=1 ELSE PIO(0x25)=0
50 J.20
1000 SETIO P, 0xFC00
1010 PIO(0x04)=0
1015 PIO(0x09)=0xA7
1020 PIO(0x04)=1
1030 RETURN
```

This code does not need any further interpretation. I've enabled the single step trace option so I can show you that the code does indeed work as designed.

In **Screenshot 1**, I've used an ALEC console command



■ SCREENSHOT 1. I used the ALEC LIST command to display the contents that were loaded into the SPECTRUM ACE 2a's SRAM. Multiple ALEC programs can be loaded into the SRAM area.



■ SCREENSHOT 2. This shot speaks for itself. I tapped the spacebar to walk through the program line by line.

to list the program we just wrote and loaded. Loading the ALEC program into the SPECTRUM ACE 2a's SRAM is as simple as selecting "Send Text File" in HyperTerminal and selecting the file to send to the ACE 2a. All that is required to run the downloaded program in SRAM is to enter "RUN" or "EXE" at the console prompt. Since we included the single step trace instruction, a tap of the spacebar walks us through the code line by line. Note that the shorthand I used for output and jump is expanded in the listing.

As you can see in **Screenshot 2**, I tapped the spacebar through the subroutine into the main logic which is continually testing the MAX7301 I/O expander's I/O 4 input. Once the I/O 4 GPIO pin state is read, the acquired logic state held in the fast variable "a" is printed to the console.

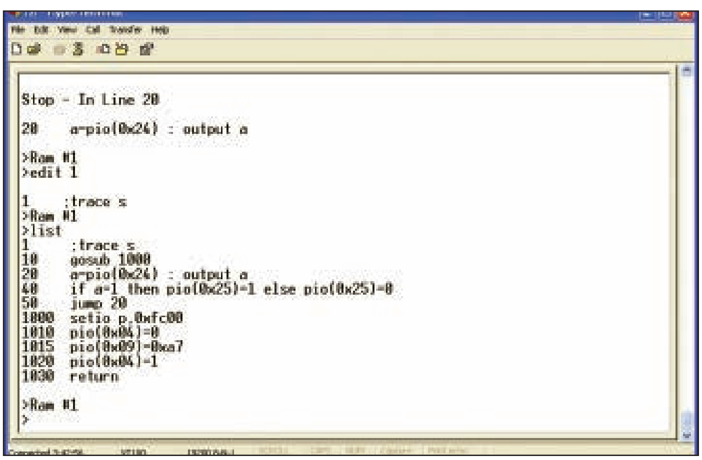
The first pass through the code at line 20 reads a logical 1. I wired in one of the ACE evaluation board's on-board LEDs to the MAX7301's I/O 5 GPIO output and it illuminated following the execution of the code in line 40. Before executing line 50, I forced the I/O 4 input logically low. As expected, the second pass through line 20 yielded a logical low and the LED went dark following the execution of the line 40 code. If you take the time to read the expander datasheet and follow the flow of configuring, reading, and writing the part, you'll appreciate what ALEC is doing behind the scenes. All of the SPI communications and internal bit twiddling that the expander requires is performed under the covers by ALEC.

Before we leave the MAX7301 I/O expander, I want to show you how easy it is to transfer our PIO I/O program to the SPECTRUM ACE 2a's Flash. **Screenshot 3** shows you how I used the ALEC "EDIT" command to alter line 1. With the single step trace instruction disabled in SRAM program #1, entering the ALEC "PROG" command as shown in **Screenshot 4** will compile the SRAM code and load it into the first program slot in Flash. Entering "FLASH" at the console command prompt takes us to the first program in Flash which we just compiled and transferred. The ALEC "LIST" command works in the Flash area just as it does in the SRAM area. Entering "BOOT 2" at the console command prompt will run the first program in FLASH (that's our MAX7301 I/O expander I/O program) upon reset or power-up. To disable automatic boot from Flash, "BOOT 0" is the console entry to use. While we're on the subject of ALEC boot modes, let's do some booting from a USB thumb drive.

EASY USB

Thanks to ALEC, USB has never been this easy. The SPECTRUM ACE evaluation board's USB portal is under my Canon's macro lens in **Photo 4**. I'm going to show you how easy it is to create a file, load that file onto a USB thumb drive, and boot the file.

We'll begin by performing a POR (Power On Reset), purging the SRAM area and erasing the Flash area of the ACE 2a. Take a quick look at **Figure 3**. There you'll find our memory-mapped I/O address for the USB portal which happens to be 0xFA00. While you were perusing **Figure 3**, I performed yet another POR on the ACE 2a and mounted a blank thumb drive. To gain access to the thumb drive, we need to establish the USB memory-mapped I/O address just as we did with the MAX7301



■ SCREENSHOT 3. ALEC allows the program that is currently loaded in SRAM to be edited via the console. Here, I eliminated the trace instruction.

I/O expander. Check out the SETIO U (U for USB) console command in **Screenshot 5** which opens the door to the thumb drive's innards. While you were looking at **Screenshot 5**, I wrote a little ALEC program called USBBOOT.TXT using a text editor called NoteTab, and used HyperTerminal to download it to the ACE 2a SRAM:

```
10 p."I BOOTED FROM USB.."
```

As you can see in **Screenshot 5**, I saved the original USBBOOT.TXT and saved another copy of USBBOOT.TXT called ALECBOOT.ALC. The idea behind generating ALECBOOT.ALC is that we'll use that file as our thumb drive boot file. To boot ALECBOOT.ALC, we'll need to issue a BOOT U and a BOOT 5 via the console. The BOOT U command saves the USB portal's memory-mapped address, while BOOT 5 instructs the SPECTRUM ACE 2a to load the ALECBOOT.ALC program into SRAM and execute it at reset. The fruit of our labor is captured in **Screenshot 6**.

ALEC also allows the user/programmer to access the thumb drive using DOS-like commands. For instance, CD performs a change directory and MKDIR creates a new directory on the thumb drive. Reading and writing the contents of data files are also in ALEC's USB thumb drive repertoire.

ALEC CAN CYPHER, TOO

Most sensor-based applications capture the raw output of a particular sensor and convert the raw data to something meaningful to a human or another peripheral device. ALEC allows us to easily obtain sensor input, mathematically manipulate it, and display it.

I have an LM34C temperature sensor and recall the ACE 2a comes standard with an ADC. The DS2450 is capable of spitting out a scaled 16-bit conversion result. With the LM34C emitting +10 mV/°F and the DS2450 converting the LM34C output, I'd say we've got to do some math to get a human-readable temperature value.

We'll let ALEC control the analog-to-digital (A/D) conversion process and do the math. ALEC's A1D() hardware operator gives us access to the resources of the DS2450. Once again thanks to ALEC, initializing the DS2450 and performing conversions is a walk in the park.

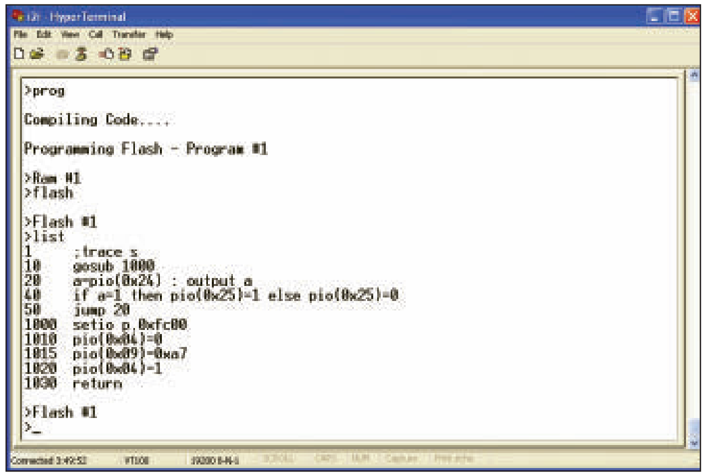
I've initiated some basic DS2450 functionality in **Screenshot 7**. The a1d(i) operator initializes the DS2450 setting its input voltage range between 0.00 and +5.00 volts. The DS2450's output resolution of 16 bits is also configured by the a1d(i) operator. The A/D per step resolution is 0.00007629 volts which is computed as follows:

```
5.0 volts /65535 steps = 0.00007629 volts/step
```

ALEC associates the DS2450's A, B, C, and D inputs to 0, 1, 2, and 3, respectively. So, I threw a wire between the DS2450's A A/D input and the SPECTRUM ACE 2a's VCC power pin. A 16-read averaging A/D conversion is kicked off in this manner:

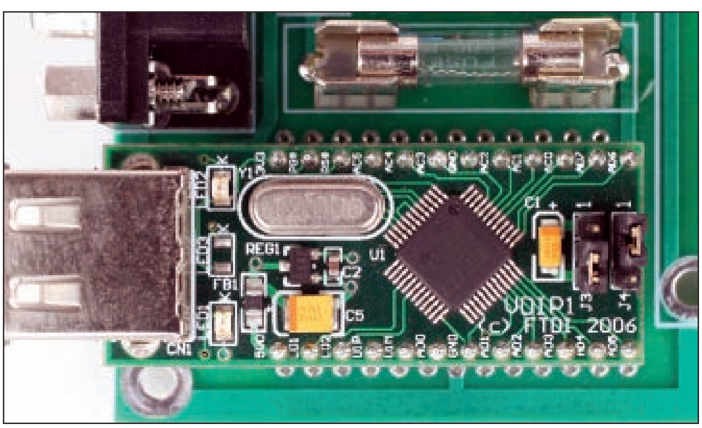
```
a1d(a,0)
```

If we want to output the value returned by the 16-read averaging A/D conversion to the console, we've got to precede the conversion instruction with a PRINT

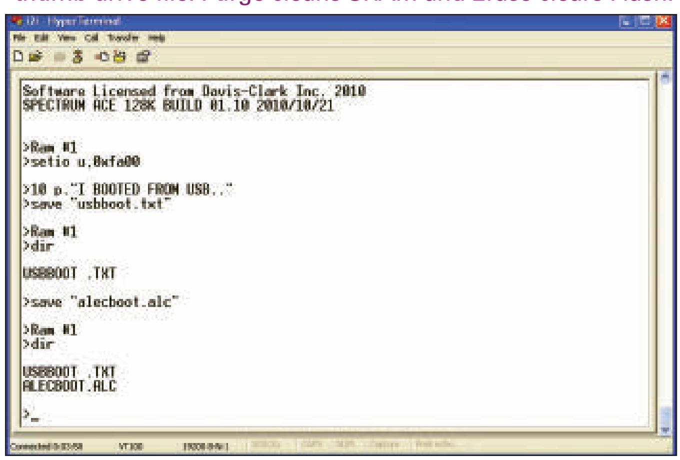


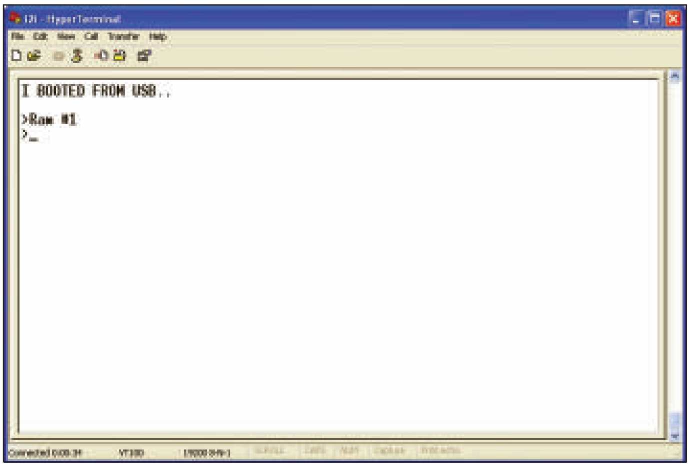
■ SCREENSHOT 4. Once we have programs in nonvolatile Flash, we can choose to execute them at boot time or call upon them after a POR or reset. Multiple programs can reside in SRAM and Flash. Each program is identified by a number.

■ PHOTO 4. If you're a Design Cycle regular, you've been down the Vinculum trail with me before. All of that Vinculum theory and operation we talked about has been stuffed into the bowels of ALEC.

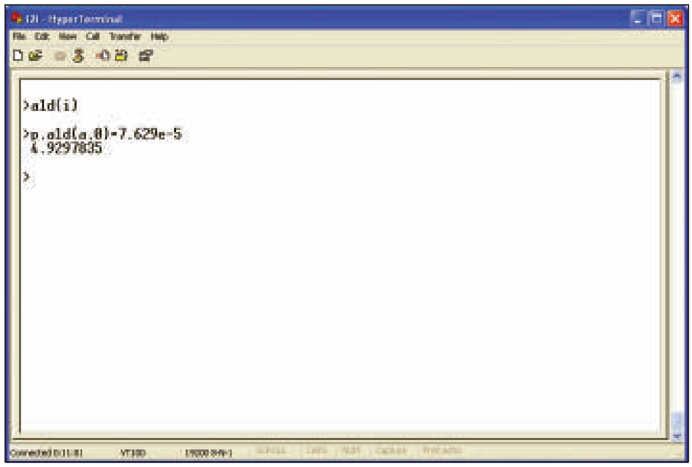


■ SCREENSHOT 5. We want to start clean. That way, you can follow along more easily as I build, load, and boot the thumb drive file. Purge cleans SRAM and Erase clears Flash.

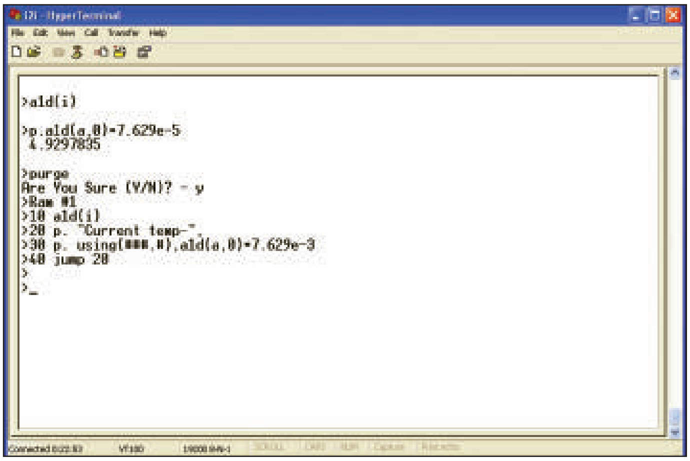




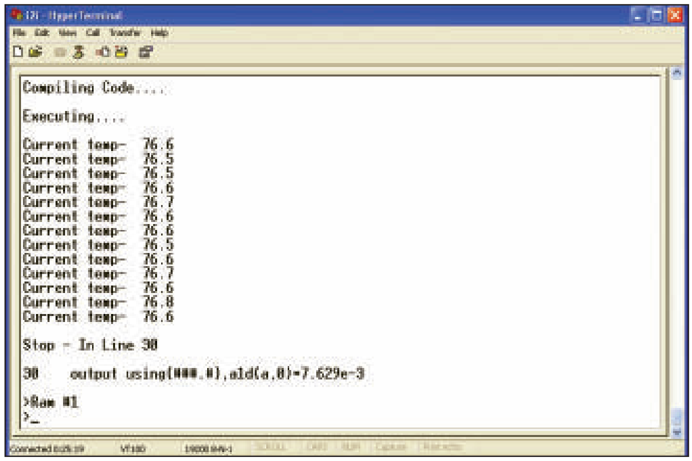
■ SCREENSHOT 6. It just doesn't get any easier than this. ALEC can also oversee loading and booting of SRAM and Flash images, as well.



■ SCREENSHOT 7. We're operating in console mode here. We could send the output to an LCD by simply replacing the p in p. with an L. That's ALEC working.



■ SCREENSHOT 8. Without leaving the ALEC environment, we've morphed from console commands to a working program.



■ SCREENSHOT 9. ALEC does the work and we get the glory.

command (p.). A raw 16-bit count doesn't tell us much. So, we'll apply the volts per step value to the raw 16-bit conversion output. Here's what we have thus far:

```
p.a1d(a,0)*7.629e-5
```

As you can see in **Screenshot 7**, our SPECTRUM ACE 2a's VCC power rail comes in with an average potential of +4.93 volts.

Taking into account the LM34C's +10 mV/°F conversion factor, our volts per step per °F is equal to 0.007629. With that, we have everything we need to assemble an ALEC program to read and convert the LM34C's output voltage to temperature. Here's the code:

```
10 a1d(i)
20 p. "Current temp-",
30 p. using(###.#),a1d(a,0)*7.629e-3
40 jump 20
```

I've thrown in a formatting directive to force the temperature value to assume a 999.9 numeric display format. Otherwise, there are no other surprises in our LM34C code.

The code is downloaded and ready to roll in **Screenshot 8**. I wired in the LM34C and kicked off our temperature code to get the temperature results that are generated in **Screenshot 9**.

GETTING SERIOUS IN A HURRY

That's the idea behind ALEC and the SPECTRUM ACE 2a. We performed some serious GPIO operations and even booted from a thumb drive by melding ALEC mnemonics with standard everyday coding techniques. Now that you know how to input data, output data, convert data, and display data using ALEC and the SPECTRUM ACE 2a, you are ready to quickly create some serious ALEC-assisted ACE 2a applications. **NV**

Fred Eady can be reached at fred@edtp.com.

SOURCE

I2I Controls
SPECTRUM LITE; SPECTRUM ACE 1a; SPECTRUM ACE 2a; MAX7301 I/O Expander; SPECTRUM ACE Evaluation Board
www.i2icontrols.com

■ BY LOUIS E. FRENZEL W5LEF

THE WIRELESS FREQUENCY SPECTRUM CRISIS. REALLY? WHAT IT IS, HOW TO FIX IT.

Is there really a crisis going on with our wireless frequency spectrum? It depends on who you ask, but the general consensus is that there is a crisis. I'm not sure it is a major disaster waiting to happen this year because in many ways, there have been many smaller crises over the years. Some of which we are still dealing with. Of course, it is the job of the Federal Communications Commission (FCC) and its government cousin the National Telecommunications and Information Administration (NTIA) to monitor things, solve and anticipate problems, and head them off before we have a crisis. Neither agency has done very well in this regard. Let's take a look at the spectrum and what is going on.

DEFINE FREQUENCY SPECTRUM

The frequency spectrum is a fuzzy thing to explain. It is that range of frequencies used by all radio or wireless services. It is air or free space. It is what has been called the "ether." It is the invisible medium that supports the transmission of electromagnetic waves. Here's the issue. Since all signals generated are radiated into free space, they potentially can impact any one. With lots of radios trying to transmit simultaneously on the same frequencies, interference is a major problem.

In the early days of radio, the frequency spectrum was wide open. The frontier. However, as radio technology advanced, things started getting dicey. The interference problem threatened to slow the growth of products and services so the government took action. The FCC was founded with the Communications Act of 1934 that put rules and regulations in place to manage the spectrum. The FCC's job is to regulate all communications services, not only all radio and TV but also telephones, satellite, and cable. For wireless, it means that essentially the FCC's job is to allocate spectrum to each kind of service, then issue licenses to use it and enforce those rules. That was certainly regulation that was needed. Up until recently, it has worked out okay. But with so many new wireless products and services, we have essentially run out of space. And like land, there is only so much of it available. You still have to allocate and license to make wireless available to those who want it.

The radio spectrum itself extends from roughly 30 kHz to beyond 300 GHz. It seems like more than enough to go around. With the growth of technology, wireless innovation has exploded making far more products available. Take a look at the designations below to see how we generally divide up and categorize the radio spectrum. Keep in mind the power line frequency is 60 Hz and the audio frequencies are from 20 Hz to 20 kHz. Voice only is about 300 Hz to 4 kHz. We don't do radio at these frequencies, but there are exceptions. For example, the Navy's Extremely Low Frequency (ELF) system operates on about 76 Hz to communicate with submerged subs worldwide.

Low Frequency (30 kHz to 300 kHz)

Not much down here. Propagation is by ground wave, so range is limited unless you use lots of power. Some aeronautical and marine navigation systems still use this space. Accurate time station WWVB in Colorado transmits on 60 kHz and pretty much covers the US with its big antennas and tens of thousands of watts of power. I have a watch that picks up this signal and synchronizes it to the time signal that has "atomic" accuracy as based on a cesium atom clock.

Medium Frequency (300 kHz to 3 MHz)

A good range. More ground wave propagation. Limited range during the day but signals can bounce off the ionosphere at night producing long range communications and interference. This range is mostly occupied by AM radio broadcast stations from roughly 535 to 1710 kHz. You can see why some AM stations turn their power down at night or redirect their antennas to minimize interference to other stations using the same frequency. There are also some marine and aeronautical services in this range, along with the ham radio 160 meter band.

High Frequency (3 to 30 MHz)

This is what we call shortwave. Shortwave signals can travel around the world thanks to the unique bending of signals by the ionosphere. This kind of propagation is called sky wave. The HF bands are mostly taken up by worldwide international broadcasting and amateur radio.

Very High Frequency (30 to 300 MHz)

This band of frequencies is loaded with stuff. Propagation is direct wave or line of sight (LOS) transmission). First is broadcast TV from about 50 MHz up to about 698 MHz. FM radio is from 88 to 108 MHz. There are loads of two-way radio services including aircraft, marine, police, public service and safety, military, and amateur radio. This is where some of the problems lie and conflicts exist, especially in the public sector radio. Police, fire, and other services like Homeland Security and Border Control have grown significantly making new frequencies unavailable. It is a real hodge podge.

Ultra High Frequencies (300 MHz to 3 GHz)

Again, this is a really busy segment with all sorts of public safety, military, wireless microphones, amateur radio, and whatever. It's a busy sector. Propagation is direct LOS. This is also where all the cell phone frequencies lie. These extend from about 800 MHz to 950 MHz, and then with chunks in the 1.7, 1.8, 1.9, 2.1, and 2.3 GHz ranges. It is really chopped up. Now, with the increasing demand for more cellular service — especially to handle wide bandwidth services like video — suddenly we have a crisis. Other services in the range are Wi-Fi wireless LAN networks from 2.4 to 2.483 GHz. Bluetooth is also in this range, as is a bunch of other short range technologies like ZigBee. GPS navigation is at 1.575 GHz. Incidentally, any frequency over 1 GHz is generally regarded as microwave.

Super High Frequencies (3 to 30 GHz)

It has taken years to create components and circuits that could operate well in this nose-bleed territory. Now, it's routine with modern integrated circuits. This range of frequencies is used for satellites, radar, and a mixture of radio communications like wireless LAN, telephone backhaul, and the like. It too is being used up quickly, but there is probably some room for growth here but the range is severely limited by physics.

Extremely High Frequencies (30 to 300 GHz)

These are also called millimeter waves since at 300 GHz, the wavelength is one millimeter. There is not much in the range because of range limitations and other issues, but there is space for growth. There is some satellite, radar, and other military stuff. The 60 GHz band is being developed for more commercial use. Some telecom backhaul operates in here, and the new car radars for speed and braking control use frequencies in the 77 GHz range. Lots of potential here.

Spectrum On A Cable

Did you know that you can use any portion of the spectrum, as long as it is contained on a cable? If it is on a cable, it does not radiate and become an interfering radio signal. That's what cable TV does. It puts almost all the spectrum from about 3 MHz up to about 1 GHz on an RG-6 coax cable to carry lots of TV channels and other things like music, movies, and high speed Internet service. No need to ask the FCC for permission, as long as any signals are contained. We can even put the entire radio spectrum above on a single fiber optics cable. Cables are expensive compared to free space, but sometimes we have to use them.

SO, WHAT IS THE SO-CALLED CRISIS?

As you have seen, certain frequencies are best for certain types of communications. The most useful ones are the VHF, UHF, and low microwave frequencies where we can transmit LOS over distances up to several miles. They are reliable and do not carry over the horizon to interfere with other states, cities, counties, or countries. At these shorter wavelengths, practical antenna lengths are short and reasonable. So, the real crisis is in dividing up and partitioning the frequencies from about 30 MHz to 3 GHz. That is really where all the wireless action is today.

The crisis centers around getting more cellular frequencies so wireless carriers can expand. Furthermore, the big demand for iPhones, Droids, and other smart phones are putting stress and strain on the wireless networks since some have not upgraded fast enough to 3G or 4G speeds that permit more video downloading, gaming, and other high bandwidth activities. As everything has gone digital, higher bandwidths have been needed, especially for video. As each assigned channel gets more bandwidth, spectrum withers.

Second, the government wants to implement its grand National Broadband Plan, a US plan to make sure every citizen has access to fast Internet services. While a large percentage of citizens already has such access because they live in the larger cities and can afford to pay for it, a huge percentage doesn't. These are folks in the small towns and rural areas that do not have cable, DSL, or, in some cases, even cell phone service. There are some areas in south Texas close to where I live that are still today wireless dead zones. There are others; more than you think.

Another crisis lies in the public service radio sector. They too have run out of assigned spectrum and are seeking more. That could be a real crisis unless some nationwide network is built that is guaranteed to work.

TECHNOLOGY TO THE RESCUE

Since there is no more spectrum, the basic idea up to now has been to use technology to make more efficient use of the spectrum we do have. We have nearly run out of options here. Over the years, many new electronic techniques have been developed to try to squeeze more into the existing space. There have been many new modulation and multiplexing methods, as well as digital data compression and error coding that have really kept wireless alive in limited spectrum. Here is just a short list of methods that really help.

MOVE UP IN THE SPECTRUM

There is more space at the higher frequencies. That is already being done. As technology permits, that will continue. It is more expensive to implement microwave and millimeter wave gear, and there are other limitations. However, progress is being made as we find ways to do it technologically at reasonable cost.

DIGITIZE EVERYTHING

Going to digital voice, video, and data usually uses more spectrum but thanks to some great new techniques, we have been able to put more voice calls and video into the same space. Multiplexing is a great example. Digital cellular standards put three, then eight calls per channel with time division multiplexing. That is an example of the popular worldwide GSM standard. Code division multiple access (CDMA) is another multiplexing method that puts up to 64 calls per 1.25 MHz channel. What helped that happen was voice compression. These are mathematical algorithms that scrunch the digital voice data down into a fraction of its previous size, meaning that it transmits fewer bits faster in narrower bandwidths and takes up less memory space. Digital gave us not only more spectrum efficiency but also greater noise immunity and link reliability.

ROB PETER TO PAY PAUL

This is the FCC's technique of taking previously assigned spectrum from one service and giving it to another. That is what happened in 2009 when the FCC mandated that all broadcast TV go digital and that all spectrum from about 700 to 800 MHz be reassigned from the TV stations to others. That happened, but the FCC just didn't give it to others, it actually auctioned off that 700 MHz spectrum to the highest bidders for a bit over $19 billion. The big cell phone carriers bought most of it for cellular expansion and wireless broadband services. It is still not fully in use but it's coming on-line as companies build radios that can use that space; capital intensive base stations are being built. A chunk of that 700 MHz may also go to public service radio that really needs it. Some say the FCC would like to do more of this and has its eye on the TV spectrum again. Only about 10% to 12% of US citizens actually get their TV over the air. Most get it by cable or a growing number by the Internet. Will the FCC take more away? We shall see.

USE COGNITIVE RADIO

Cognitive radio is a technique of software-defined radio (SDR). SDR puts most of the radio functions like modulation, demodulation, multiplexing, etc., into software form and uses a processor to implement them. Cognitive radio makes use of very frequency-agile radios that can sense the presence of other signals, then switch to a clear frequency to transmit. Cognitive radios do not stay in one assigned channel. They roam to use the spectrum that is available at the time. There are only a few examples of it now in the military but the cellular industry is looking at its potential. Such smart radios simply optimize what we have now.

WHITE SPACES

White space is defined as those unused TV channels in most areas of the country. For a given region, the TV stations are spaced widely with one or two channels between to ensure that no interference occurs. These channels are selected so that they do not interfere with bordering locals. What this does is leave many unused channels at any given time in these different localities. The FCC has said that these "white space" channels can be used for other services. One of them is broadband wireless access. This whole phenomenon is being explored now as to its viability. The technology is here, but the details have to be worked out. This is a great place for the cognitive radio. **NV**

The Shorter The Wavelength, The Lesser The Transmit Range

It's a bit more complex but that is the essence of it. First, remember that the wavelength (λ) is the physical length of one cycle of a radio wave in space. You can calculate it with the formula:

$$\lambda = 300/f_{MHz}$$

The wavelength in meters is 300 divided by the frequency in MegaHertz. Therefore, the lower the frequency, the longer the wavelength and also, by the way, the antennas. At medium frequencies, practical antennas are hundreds of feet long. At the cell phone frequency of 900 MHz, the wavelength is only 0.333 meters. A practical antenna there is only a few inches long. No wonder there is a battle for VHF and UHF/microwave bands.

Anyway, physics tells us that the received power is proportional to the square of the wavelength. Wow, the square. At the higher frequencies, you must boost signal power for a given distance. The received power is significantly less at the shorter wavelength or higher frequencies for the same distance. Received power also drops off as the square of the distance. The higher frequency and shorter range can be overcome by using more power but there is a limit to that, as well.

Get A Look At The Real Spectrum

The NTIA has a great spectrum chart on their website at **www.ntia.doc.gov/osmhome/allochrt.pdf**. Take a look to see just what a can of worms it really is. Hats off to those at the FCC and NTIA who maintain this mess. There are other good sources for more information on the spectrum if you want to become the next spectrum policy wonk.

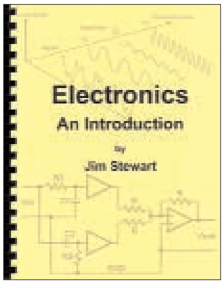
For a complete product detail visit our webstore!!

The Nuts & Volts WEBSTORE

ELECTRONICS

Electronics An Introduction
by Jim Stewart

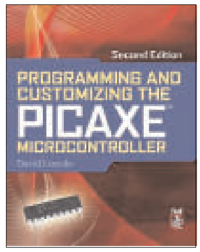
NEW!



This book is designed as an in-depth introduction to important concepts in electronics. While electronics can be highly mathematical, this text is not about calculations. It is about how electronic equipment is able to extract, process, and present information held in electrical signals. If you are in — or studying to be in — a profession that requires the use of electronic equipment, then this book will provide the insight necessary to use such equipment effectively. **$39.95***

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

UNLEASH THE POWER OF THE PICAXE!

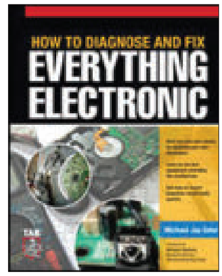


The PICAXE is a powerful and easy-to-use processor, capable of highly sophisticated projects, without the complexities and high costs of alternative chips. Beginners can produce tangible results within minutes, and experienced users can achieve truly professional results. This Second Edition has been 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*

How to Diagnose and Fix Everything Electronic
by Michael Jay Geier

NEW!

Master the Art of Electronics Repair!



In this hands-on guide, a lifelong electronics repair guru shares his tested techniques and invaluable insights. *How to Diagnose and Fix Everything Electronic* shows you how to repair and extend the life of all kinds of solid-state devices, from modern digital gadgetry to cherished analog products of yesteryear.

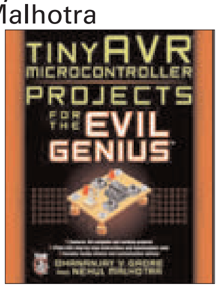
About the Author

Michael Jay Geier began operating a neighborhood electronics repair service at age eight that was profiled in *The Miami News*.
$24.95

---

tinyAVR Microcontroller Projects for the Evil Genius
by Dhananjay Gadre and Nehul Malhotra

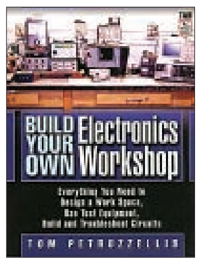
NEW!



Using easy-to-find components and equipment, this hands-on guide helps you build a solid foundation in electronics and embedded programming while accomplishing useful — and slightly twisted — projects. Most of the projects have fascinating visual appeal in the form of large LED-based displays, and others feature a voice playback mechanism. Full source code and circuit files for each project are available for download.
$24.95

Build Your Own Electronics Workshop
by Thomas Petruzzellis

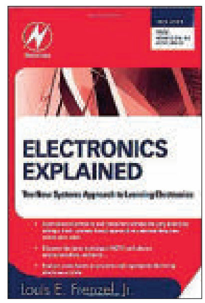
BUILD YOUR OWN DREAM ELECTRONICS LAB!



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
Sale Price $24.95

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.
$29.95

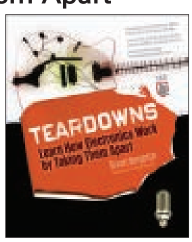
Making Things Move: DIY Mechanisms for Inventors, Hobbyists, and Artists
by Dustyn Roberts

NEW!

In *Making Things Move: DIY Mechanisms for Inventors, Hobbyists, and Artists*, you'll learn how to successfully build moving mechanisms through non-technical explanations, examples, and do-it-yourself projects — from kinetic art installations to creative toys to energy-harvesting devices. Photographs, illustrations, screenshots, and images of 3D models are included for each project.
$29.95*

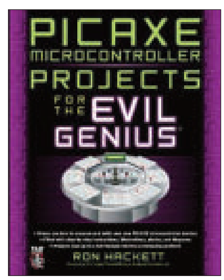
TEARDOWNS
by Bryan Bergeron

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**

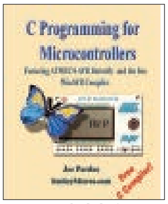
PICAXE Microcontroller Projects for the Evil Genius
by Ron Hackett



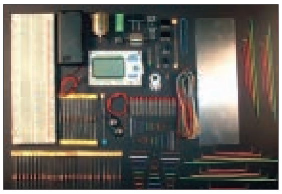
This wickedly inventive guide shows you how to program, build, and debug a variety of PICAXE microcontroller projects. *PICAXE Microcontroller Projects for the Evil Genius* gets you started with programming and I/O interfacing right away, and then shows you how to develop a master processor circuit.
$24.95

Order online @ www.nutsvolts.com
Or CALL 1-800-783-4624 today!

BOOK & KIT COMBOS



From the
Smiley Workshop
C Programming for
Microcontrollers
by Joe Pardue

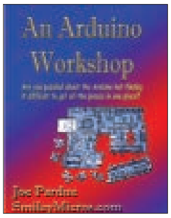


Book **$44.95**

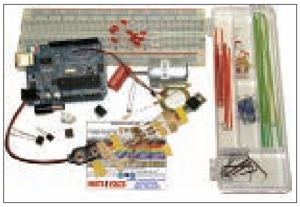
Kit **$66.95**

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

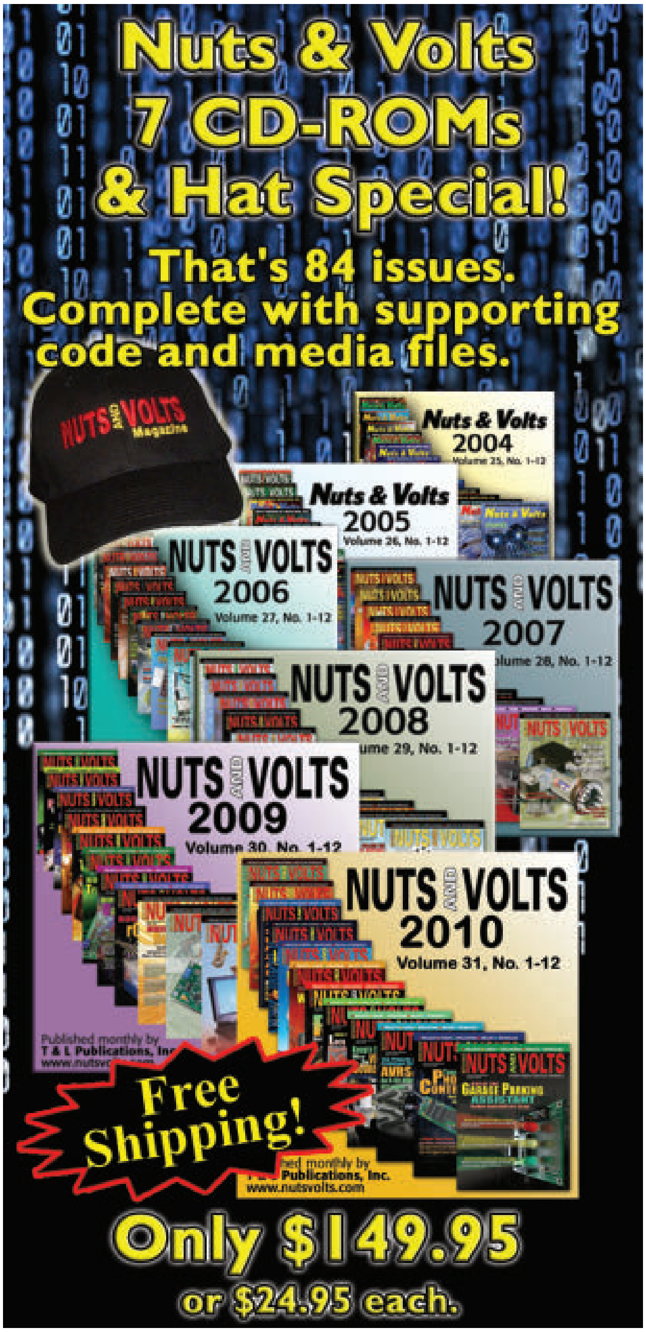


The book *An Arduino Workshop* and the associated hardware projects kit bring all the pieces of the puzzle together in one place. With this, you will learn to: blink eight LEDs (Cylon Eyes); read a pushbutton and 8-bit DIP switch; sense voltage, light, and temperature; make music on a piezo element; 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



This lab — from the good people at GSS Tech Ed — will show you 40 of the most simple and interesting experiments and lessons you have ever seen on a solderless circuit board. As you do each experiment, you learn how basic components work in a circuit. Along with the purchase of the lab, you will receive a special password to access the fantastic online interactive software to help you fully understand all the electronic principles. For a complete product description and sample software, please visit our webstore.

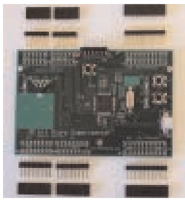
Reg Price $79.95 **Subscriber's Price $75.95**

This great little book is a concise all-purpose reference featuring hundreds of tables, maps, formulas, constants, and conversions. AND it still fits in your shirt pocket!

CALL 1-800-783-4624 today!
Or Order online @ www.nutsvolts.com

PROJECTS

32-Bit Micro Experimenter Board



The new 32-Bit Micro Experimenter is the fastest way to learn 32-bit microcontrollers.

The kit includes onboard 46 programmable I/O and USB, free software, carefully documented step-by-step experiments for USB, embedded web server, graphics & audio, wireless, RTOS, and file I/O. User pushbuttons, LEDs, and 32 kHz clock crystal. Can be used in solderless breadboard environment or stand-alone. Also supports Arduino compatible interface.

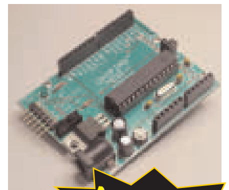
Subscriber's Price **$89.95**
Non-Subscriber's Price **$93.95**

Piezoelectric Film Speaker Kit

As seen in the November 2010 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**

CHIPINO Kit



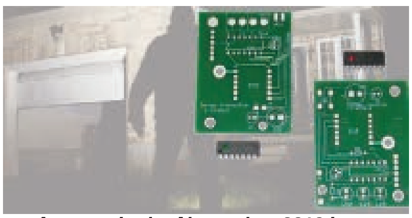
Assembled units $29.95!

The CHIPINO module is an electronic prototyping platform that is used in a series of articles starting with the March 2011 issue of *Nuts & Volts Magazine.*

Developed by the CHIPAXE Team as a bridge between PICs and Arduinos. The module was designed specifically to match the board outline, mounting holes, connector spacing, and most of the microcontroller I/O functions found on the popular Arduino module.

Subscriber's Price **$18.95**
Non-Subscriber's Price **$19.95**

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 found at your favorite parts house.

Includes an article reprint.

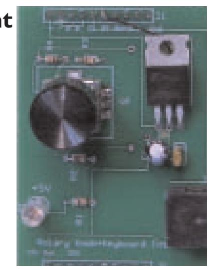
Subscriber's Price **$29.95**
Non-Subscriber's Price **$31.95**

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 of the *Nuts & Volts* website.

Subscriber's Price **$76.95**
Non-Subscriber's Price **$83.95**

The Mini Kit



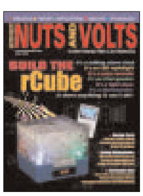
The best experiment yet for the 16-Bit Experimenter Board.

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**

rCube Talking Alarm Clock Kit

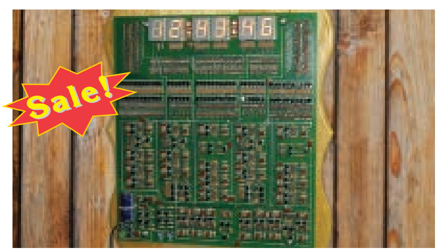
As seen on the May 2009 cover



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



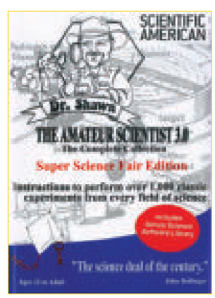
Sale!

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 4.0
The Complete Collection

by Bright Science, LLC



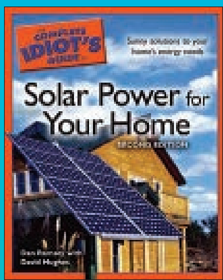
There are 1,000 projects on this **CD**, not to mention the additional technical info and bonus features. It doesn't matter if you're a complete novice looking to do their first science fair project or a super tech-head gadget freak; there are enough projects on the single CD-ROM to keep you and 50 of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

Reg $26.95 Sale Price $23.95

WE ACCEPT VISA, MC, AMEX, and DISCOVER. Prices do not include shipping and may be subject to change.

ALTERNATIVE ENERGY SECTION

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

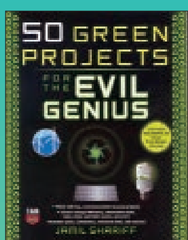


The perfect source for solar power — fully illustrated. This book helps readers understand the basics of solar power and other renewable energy sources, explore whether solar power makes sense for them, what their options are, and what's involved with installing various on- and off-grid systems.
$19.95

NEW! Green Lighting
by Brian Clark Howard, Seth Leitman, William Brinsky
Flip the switch to energy-efficient lighting!

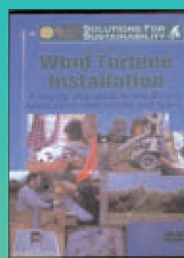
This do-it-yourself guide makes it easy to upgrade residential and commercial lighting to reduce costs and environmental impact while maintaining or even improving the quality of the lighting. Filled with step-by-step instructions and methods for calculating return on investment, plus recommended sources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

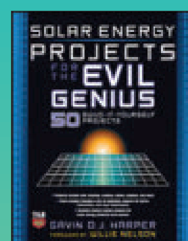
NEW! Wind Turbine Installation DVD



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.

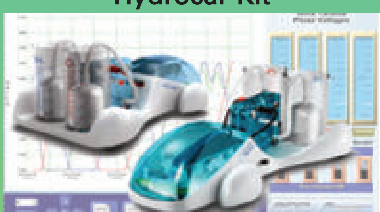
$19.95*

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



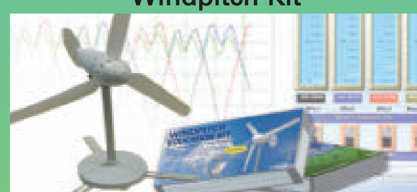
The Hydrocar is used in a couple of great projects from the series of articles by John Gavlik, "Experimenting with Alternative Energy." In Parts 10 and 11, he teaches you the operation of the Polymer Electrolyte Membrane "reversible" fuel cell.
For kit details and a demo video, please visit our webstore.

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 **$94.95**
Non-Subscriber's Price **$99.95**

ELECTRONET

ROBOTICS

MaxSonar
Ultrasonic Ranging is EZ

LV-MaxSonar-EZ
- Power-up calibration
- Smallest MaxSonar
- Low power, 2.5V-5.5V
- $29.95 USD qty. 1

MaxSonar-WR (IP67)
- Industrial packaging
- Weather resistant
- Standard ¾" fitting
- $99.95 USD qty. 1

XL-MaxSonar-EZ
- Beam pattern choice
- Real-time calibration
- High acoustic power
- $39.95 USD qty. 1

MaxSonar-WRC (IP67)
- Compact packaging
- Weather resistant
- Quality narrow beam
- $99.95 USD qty. 1

www.maxbotix.com

KITS/PLANS

AMAZING KITS!
- Clocks
- Nixies
- Levitator
- High Voltage
- Thermometer
- Stepper Motor Drivers

www.TECHKITS.com

SAM-III Geomagnetometer Kit
- 3-Axis – N-S, E-W, Vertical
- ±50,000 nT, 1-2 nT resolution
- 12 Vdc
- Complete kit includes software
- Logging with PC or standalone
- Join worldwide magnetometer network
- Starting at US$199.95

www.reeve.com/SAM3.htm

Electronic Kits
- Fun and Educational
- Discount White and Blue LEDs
- Quantity Discounts

www.bakatronics.com

QKITS.COM

50 AMP PWM
1-888-GO 4 KITS

High Quality
Electronic Kits & Modules

$59.95
UK1133

50 AMP DIGITAL PWM
(OPTIONAL DISPLAY)

FM Transmitters
Timers
Audio Amplifiers
Motor Controllers
PIC Programmers / Arduino
••• Custom Designs •••

www.canakit.com

POOR MANS SPECTRUM ANALYZER
Turns any oscilloscope or PC into a 2MHZ to 2.15GHZ RF Spectrum Analyzer.
Available as a kit
or kit with built and tested boards.
science-workshop.com

COMPONENTS

RF PARTS™ CO.
Tubes, Transistors, Power Components
Email: rfp@rfparts.com • Web: www.rfparts.com
800-737-2787 Fax 888-744-1943

Brilldea
purveyor of prototyping goods
+RGB LED Ribbon
+RGB LED Pixels
+LED Painter
+Parallax Propeller
+LED Lumen
+3.0" LCD w/ composite video input
www.brilldea.com

LEDs
Super Brights from 20¢
RGB Color Mixing 30 Pack $6.99
Assortment 120 Pack $24.99
Shipping from $3.00
Alan-Parekh.com/Store

uM-FPU V3.1
Floating Point Coprocessor
32-bit IEEE 754
SPI or I2C
DIP-18, SOIC-18
New full featured Compiler
Extensive floating point support, GPS input, FFT, 12-bit A/D, matrix operations, user-defined functions.
www.micromegacorp.com

Magnet Wire
adapt

www.adaptwire.com

POTTING MATERIALS

Resin & Silicone Sys.
Mfg. Silicone & Epoxy for Elec.
Thermal conductive
Insulation
Potting (embedding)
General
Protection
Easy reparability
g.m.barbosa@rtvsilicone.com
(401) 724-6711

www.nutsvolts.com

HARDWARE WANTED

DEC EQUIPMENT WANTED!!!
Digital Equipment Corp.
and compatibles.
Buy - Sell - Trade
CALL KEYWAYS 937-847-2300
or email buyer@keyways.com

DESIGN/ENG SERVICES

* Circuit board layouts
* Prototype assemblies

WWW.OSPREYELECTRONICS.COM
Convert your sketch or print into a quality pcb for a reasonable price. Visit us on the web or call Osprey Electronics at (208) 664 1089 (USA)

FLEXREV China Direct Manufacturing
Turn Key or Subassemblies
Components, Enclosures, Keypads
$0.007 per soldering point
2 layer PCBs $0.14/in2
Small jobs welcome
FLEXREV.COM

MISCELLANEOUS FOR SALE

ESTATE LIQUIDATION!
ELECTRONIC WORLD STORE CLOSED! $250,000 INVENTORY: NOVELTY TELEPHONES, WATCHES, CLOCKS, BUTANE LIGHTERS, POCKET KNIVES, SWORDS, THROWING KNIVES, CALCULATORS, WIRELESS HEAD PHONES, SUNGLASSES, PEN AND PENCIL SETS, READING GLASSES, STROBES, SECURITY CAMERAS AND MONITORS.
ISE PH: **956-444-0004**; **888-351-5550**
DETAILS AND PICTURES
WEB: **www.iseliquidator.com**

ENERGY SOLUTIONS

Save Money On
Your Electric Bill
www.sunny-solutions-shop.com
800-315-0309

SURPLUS

SURPLUS ELECTRONIC PARTS & ACCESSORIES
Over 18,000 Items in Stock.
Cables, Connectors, Displays, Fans
Hardware, LEDs, Motors, Potentiometers
Relays, Semiconductors, Service Manuals, Speakers
Switches, Test Equipment, Tools, VCR Parts

Surplus Material Components
SMC ELECTRONICS
www.smcelectronics.com
No Minimum Order.
Credit Cards and PAYPAL Accepted.
Flat $4.95 per order USA Shipping.

TECH FORUM
READER-TO-READER

>>> QUESTIONS

Detecting Vehicle Deceleration

I want to use an accelerometer to control a 12V vehicle stop light. A mercury switch is influenced by the angle of the surface the vehicle may be located on. Any suggestions for a cheap and simple circuit? Perhaps it should respond only to a rapid increase in deceleration.

#4111 **John Powers**
Seattle, WA

Remote Generator Start By Phone

I need a method to remote-start a generator by calling it.

#4112 **Bill Fitzpatrick**
Pepperell

Sequential Start Bell Controller

In German church towers, bells are pealed with reversing motors or magnetic-repulsion devices. Multiple-bell peals generally begin with the smallest bell, with bells of increasing size added every 10 seconds or so, until all are pealing. At the end of the peal, they are stopped in the same order. American bell-ringing timers don't offer this feature, and all bells start and stop at once. I'm looking for a circuit with several relay outputs in which each relay switches on in sequence every 10 seconds or so when current is applied, and switches off in the same order when current is cut. Basically, it is a power sequencer circuit that is expandable to more outputs if bells are added in the future.

#4113 **Daniel**
Boise, ID

Water Level

I need to come up with an inexpensive solution to determine the depth of the keel of a boat. Nothing can be attached to the boat because it will be used on other vessels. Mechanical solutions don't work because of the various sizes and shapes of the keels. One idea I had was a simple pressure measurement where a diver would take a measurement probe to the keel and the depth would depend on the water pressure at that level.

It sort of works, but the keel depth can be from two feet to five feet, and the pressure difference is very small.

I haven't been able to find a transducer that doesn't cost hundreds of dollars, so ...

Am I over-thinking the problem or over-engineering the solution?

#4114 **Stephen Mann**
Westford, MA

LED/LCD Digital Counter

I am looking for a fairly large (6-8 or 10-12 inch high) LED or LCD, two digit, digital display which could be changed by using perhaps one button to increase (by one at a time) and one button to decrease the displayed value..., i.e., 00 to 99.

It also would be good to just use a numbered keypad to enter the value.

Another useful feature would be to turn on and off (flashing at a chosen rate) the display to indicate urgency.

This is to be in an office area where they are serving the public. Most of you have been where there is a service counter and you need to "take a number" to secure your place in line. Often, they will have a "Number Being Served" display to show you where you are in line.

Well, my application would be to enable the employees (they can see the display from a distance at their desks) to view how many people are currently waiting to be seen. If there are not so many, the employee can afford to give the customers a bit more time if needed or if very busy, will have to keep the visit as brief as possible.

Right now, they are using an old mechanical flip-number type display which is a rather awkward (and not too state-of-the-art method) way to do it. An employee is continually jumping up from their desk (interrupting their work and time) to change the sign.

I would like to learn what the circuit design could be and what components are needed so I could construct it myself.

#4115 **Harlan Garbe**
Montevideo, MN

Scanner Mod

I have had a police scanner from RadioShack for many years. My brother is a police officer, so I sometimes listen to it. The scanner went bad and I purchased a new one at RadioShack [model #PRO2018] that looks the same as the old unit. However, I can not get the lower frequencies any more. RadioShack says they no longer make scanners that support low frequencies. Someone told me it's simple to install low frequencies on this scanner. How do I do it?

#4116 **Anonomous**
via email

>>> ANSWERS

[#2111 - February 2011]
Ground Control Rocketry Interface

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

I want to build ground equipment

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.*

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.

The solution is actually on page 79 of the February '11 issue. Saelig just introduced the IO-WARRIOR56 — a simple USB interface and 50 I/O lines.

According to the news release, a few simple lines of code are all that is necessary to address any of the I/O lines. Depending on the length of wire from the device to the relays, you may need to supply power and relay drivers. Check **www.saelig.com** for additional info and prices.

I've never done any rocketry but with this device it is beginning to sound like a lot of fun. Go for it, Cliff.

Paul J. Weijers
Canada

[#2117 - February 2011]
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 five-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.

#1 This seemed to me to be a great project if you were interested in getting into microcontrollers, such as the currently popular Arduino.

The computation of the flow rate and pulse measurement is very simple in the computer.

As it turns out — after having built a mock-up — the code for the display ends up being more verbose, but not overly complicated.

All you need to do (if I understood the problem correctly) is feed the 5V pulses into one of the Arduino's digital ports and set it up to interrupt at each pulse.

Upon receipt of the interrupt, just bump a counter. Then, the rest of the program will just output that counter, divided by the rate factor (650 or 780) to a display.

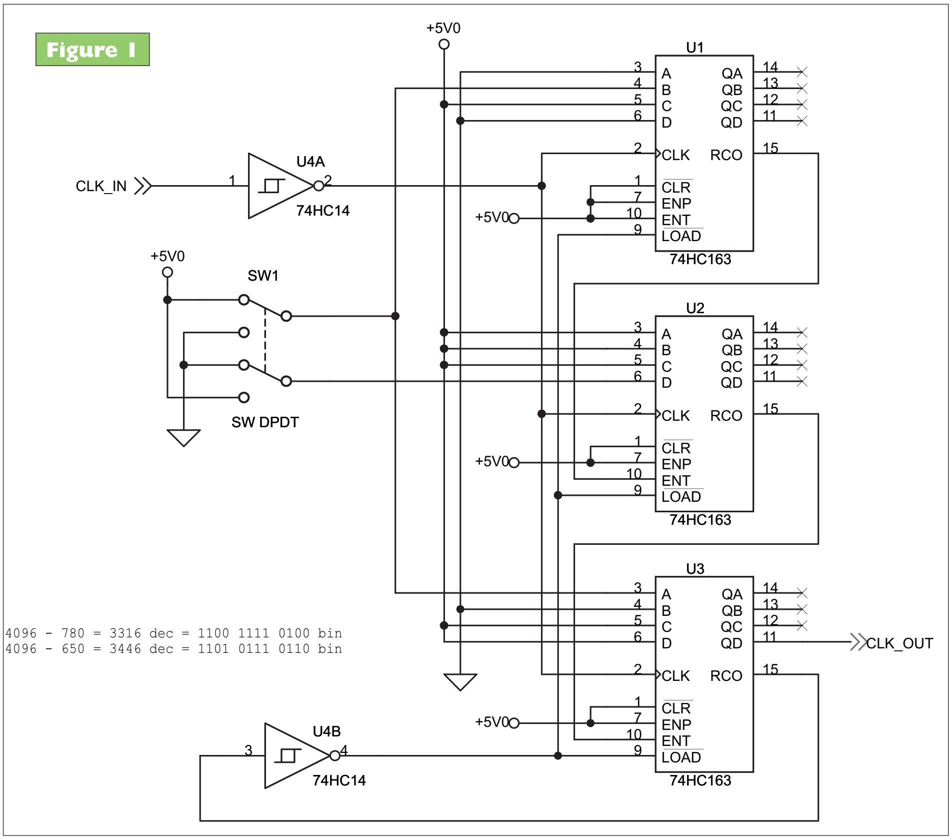
The great thing about the Arduino is the ready access of boards pre-built with displays and such (they are referred to as shields). All you have to do is plug it onto the Arduino and write the code. And, as in the case for the LCD display I chose, there is usually some sample code to run to test the shield. You can then use that code as a base for your project, which is what I did.

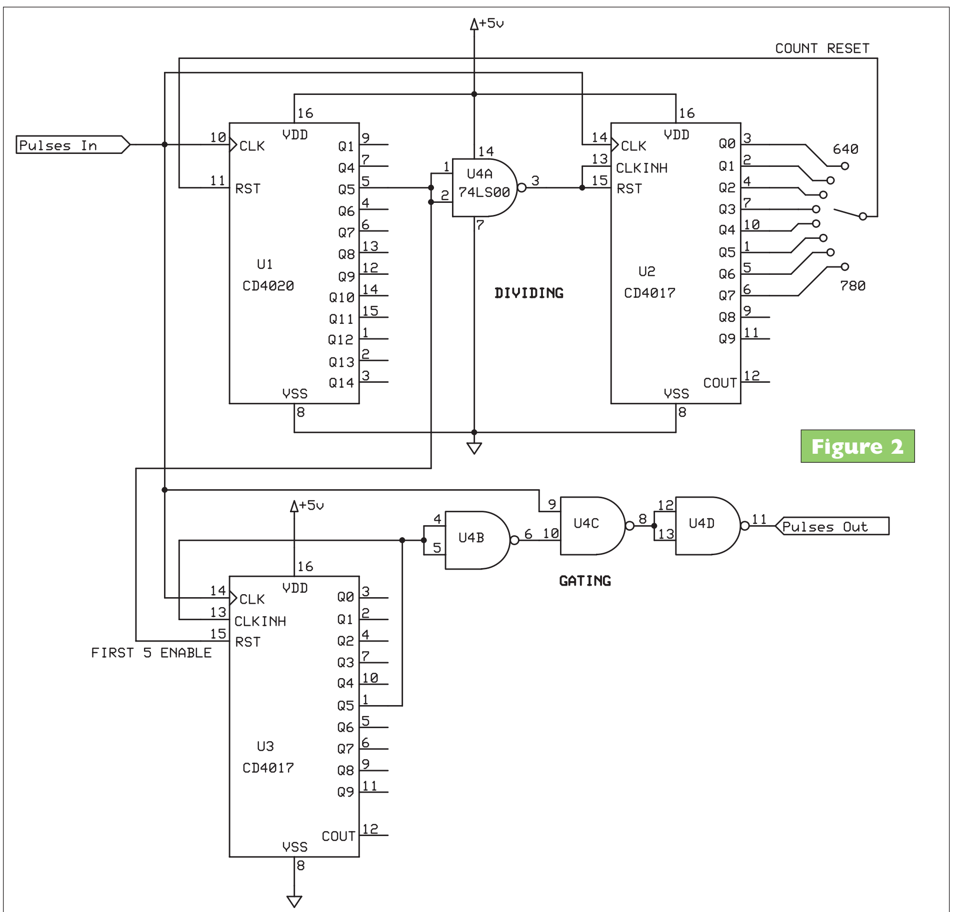
I used one more board — a proto-typing board — to join the stack of boards, where I feed the pulse input.

To summarize the mock-up, I have created a web page with pictures of the board and potential sources, a video of how to use the system as I designed it, and a link to the subsequent code.

I spent $65.50, but the hardware — for the most part — just all plugged together.

The code ended up being a bit more work than I originally envisioned, but it isn't that complex and I was able to put it all together in an evening. (I'm not a novice programmer, though.)





Here's the website: **https://sites.google.com/site/spraymeter/**. Good luck!!

Pete Lunt
Fairfax, VA

#2 Here is a programmable divider **(Figure 1)** that will divide by 720 or 650 with the flip of a switch. If more than two settings are needed, then place multiplexers in front of each bit and use switches to control the select leads. The input to the multiplexers is set to the appropriate values to get the proper divider.

Geoff Probert
via email

#3 What you need is a pulse count rescaler to go between your mass flow meter and your counting unit. Many *N&V* readers will correctly point out that this could easily be accomplished with an eight-pin PICAXE and about 10 lines of code, but I enjoyed designing this **(Figure 2)** with discrete logic and the help of my old friend, *The Engineer's Notebook* by Forrest Mims.

Since you also want to read gallons directly on your display, this design folds both corrective multiplies into one by dividing 640 to 780 pulses down to 100 (i.e., 1.00 gallons). The task is easier understood with a mathematical reduction: 64 - 78 pulses in equals 10 out, so 32 - 39 yields 5.

The circuit gates the first five pulses to the output, waits until the cycle trip limit (32-39) is reached, and resets to start over. The limit is adjusted in 20 pulse/gal increments by a selector switch.

The fifth tap on binary counter U1 takes care of the ÷32 which is cascaded into U2, then counts up sequentially to the chosen reset point. U3 is rigged to only count to five and then self-inhibit (via pin 13) until cleared by the master reset that U2 generates. U4C handles the gating of the main pulse stream from the sensor to your LED counter.

After you build and test the circuit, don't forget to paint a decimal point between the second and third indicator digits on the right side of your display for the new X.XX gallons format.

Dan Danknick
Santa Ana, CA

Comment on #1112

The idea of using a neon bulb (NE-2, etc.) is a good idea, but using a half watt resistor is a bad idea unless it has a voltage breakdown rating above the peak voltage of the fence. A typical half watt resistor would have a rated working voltage in the range from 300 to 600 volts. It would probably arc over and have little resistance to limit current flow through the bulb.

A better idea would be to use the capacitance of free space between the bulb and ground to limit the current. Connect one lead of the NE-2 to the hot wire of the fence. This may be all you need to ionize the gas in the bulb, depending on the peak voltage and rise-time of the pulse. You can always attach a short piece of wire — from a few inches to perhaps a foot — to the other lead of the bulb and let it hang free. This will increase the capacitance to ground, and will more readily ionize the gas in the bulb.

This is the principle used by the early automotive timing lights where a neon flash tube was connected in series with the top of the spark plug. You might be able to find one of the old style timing lights somewhere and add a spark plug in series with it. Then you've got your indicator.

Doug Glenn K3ZMG

LOOK FOR ■ SEARCH FOR ■ FIND

ADvertiser INDEX

Find your favorite advertisers here!

BlackJack SolderWerks Rework Systems

The BK7000 & BK7050 from *BlackJack SolderWerks use a highly efficient quartz infrared heater system that provide fast heat up and utilizes a feedback control circuit to optimize the PCB pre-heat operation.

They are designed to aid the reworking operation for large and multilayer PCBs (such as game consoles and motherboards) that use either traditional or lead free solder.

Both systems have three modes of operation.

Type 0: for single temperature heating using an internal temperature sensor.

Type 1: for more precise temperature control using the supplied external temperature probes.

Type 2: for a fully automated time and temperature based profile mode.

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

Item# **CSI3303S** **$288.00**

250mm x 200mm (9.8"x7.8") Pre-Heat area

www.CircuitSpecialists.com/BK7000

Item# **CSI5505S** **$419.00**

300mm x 300mm (11.8"x11.8") Pre-Heat Area

www.CircuitSpecialists.com/BK7050

*BlackJack SolderWerks is a Circuit Specialists, Inc. brand.

BlackJack SolderWerks Hot Air Rework Station

With Digital Display, Mechanical Arm & 70w Soldering Iron

The BlackJack BK5050 Repairing System is a multipurpose reworking station that incorporates a Hot-Air gun and a 70 watt soldering iron which is appropriate for traditional solder or lead free solder. The hot-air gun is equipped with our BlackJack Solderwerks hot-air TRIPLE PROTECTION SYSTEM which provides (1) System Cool Down, (2) Auto System Sleep, and (3) Overheat Protection.

Item# **BK5050** **$169.00**

www.CircuitSpecialists.com/BK5050

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**

www.circuitspecialists.com/CSIPPS55T

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.

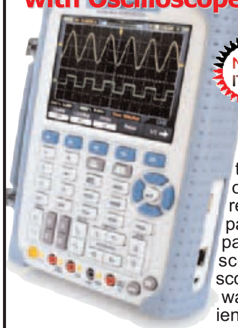
360V/150W **(CSI3710A) $349.00**

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**

Ideal for Law Enforcement, Post Fire Inspection, Plumbing, Facilities Maintenence, Security Companies, & Many Other Uses!

Aardvark II

Dual Camera Wireless Inspection Camera With Color 3.5" LCD Recordable Monitor

Your Extended Eyes & Hands!

See It! Clearly in narrow spots, even in total darkness or underwater.

Find It! Fast. No more struggling with a mirror & flash light.

Solve It! Easily, speed up the solution with extended accessories.

Record It! With the 3.5" LCD recordable monitor, you can capture pictures or record video for documentation.

Full specifications at www.CircuitSpecialists.com/aardvark

The Aardvark Wireless Inspection Camera is the only dual camera video borescope on the market today. With both a 17mm camera head that includes three atachable accessories and a 9mm camera head for tighter locations. Both cameras are mounted on 3ft flexible shafts. The flexible shaft makes the Aardvark great for inspecting hard to reach or confined areas like sink drains, AC Vents, engine compartments or anywhere space is limited. The Aardvark II comes with with a 3.5 inch color LCD monitor. The monitor is wireless and may be separated from the main unit for ease of operation. Still pictures or video can also be recorded and stored on a 2GB MicroSD card (included). The Aardvark's monitor also has connections for composite video output for a larger monitor/recorder and USB interface for computer connection. Also included is an AC adapter/charger, video cable and USB cable. Optional 3 ft flexible extensions are available to extend the Aardvark's reach (Up to 5 may be added for a total reach of 18 feet!).

Item # AARDVARK II **$249.00**

Hot New Product!! Low Cost **$99** Aardvark Jr Inspection Camera

Full details At: www.CircuitSpecialists.com/AardvarkJr

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**