

NUTS AND VOLTS

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December 2011

EVERYTHING FOR ELECTRONICS

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Big Medicine For Your Little Projects

SparkFun
ProtoSnap
Pro Mini
Review

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LI-FI (Light Fidelity)
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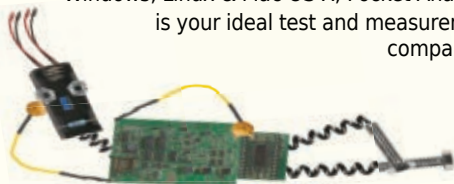
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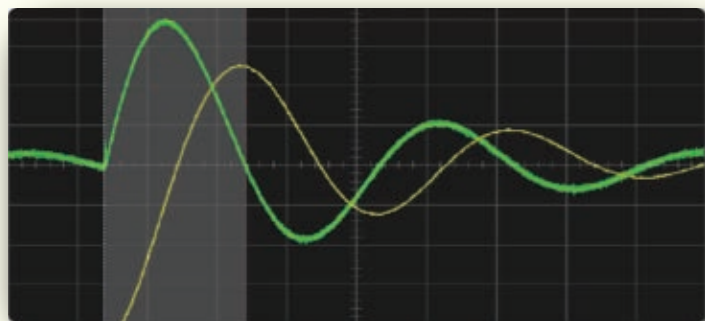
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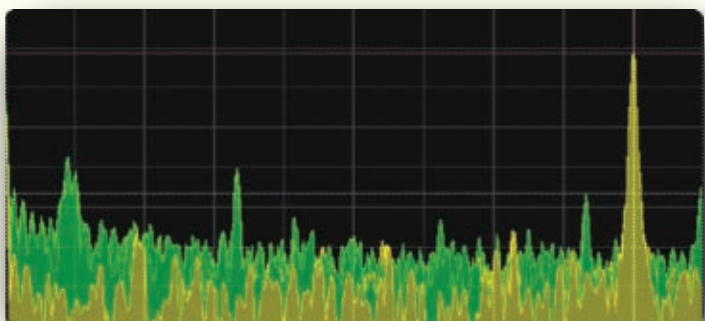
Protocol Analyzer



Digital Oscilloscope



Spectrum Analyzer



bitscope.com/nv



*Happy Holidays
From: Pololu*

Nuts & Volts December 2011

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The DL-020 Sequential Logic Trainer

introduces concepts of sequential logic design, which is the final basic elements to understanding microprocessor and microcontroller logic.



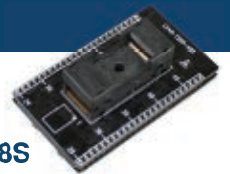
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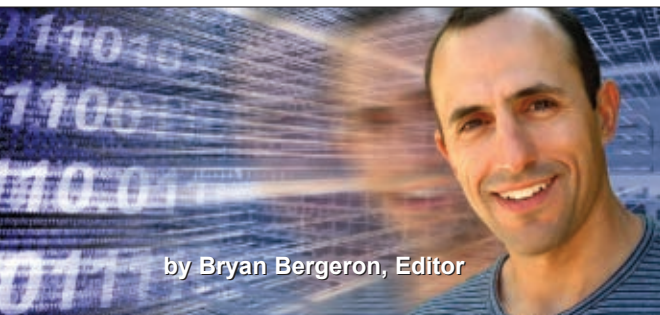
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PRO-S Lab

Breadboard with External Power & Jumper Wires



by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

LI-FI

The US energy efficiency legislation for light bulbs has been a boon for alternatives to the traditional incandescent bulb, including the LED. Energy issues aside, I use LED lamps for my desk and workbench because they're small, unobtrusive, and give off little heat.

Still, there's a lot of energy being wasted by LED-based lighting — especially if you think of the light they generate as unused bandwidth. Making use of this bandwidth is the basis of LI-FI (Light Fidelity) which has many parallels with WI-FI.

Proponents of LI-FI contend that room light, automobile lights, interior aircraft lights, and street lights all represent under-utilized bandwidth that can carry everything from voice communications and HDTV to intelligent navigation signaling between cars. If you want a great vision of what's possible with the technology, check out the free TEDtalks podcast, "Wireless Data From Every Lightbulb," available on iTunes.

Communications with light is nothing new. Roman soldiers used polished shields to reflect sunlight when signaling during battle. Commercial, secure, line-of-sight laser communications systems have been around for decades. I've used a DIY He-Ne gas laser and telescope system to communicate over five miles, but at modest bandwidth. And, of course, much of the phone system is based on optical transmission and switching.

IR light signaling has been around for some time. You probably own at least one IR remote. However, as with UV light, you wouldn't want to bathe a room with IR light because it can damage your vision. The real R&D activity is around visible light. There's plenty of bandwidth available, and it's not likely that you'll inadvertently stare into a bright light and burn your retinas.

As with RF communications, the transmission process is straightforward and doesn't take much in terms of hardware. Reception is the sticking point. There are issues of inadequate signal strength, how to handle multipath signals formed by light reflecting off of different objects and arriving at the receiver out of time, and interference from other light sources, just to name a few.

So, assuming I've piqued your interest, where do you begin? Start simple. Get an ordinary red LED and phototransistor — each coupled to your favorite microcontroller — to communicate with each other. Once you've managed a simple simplex serial connection, go for full duplex (two-way) communications.

To give you an example of what's involved, I've been

experimenting with parallel data streams using red, green, and blue LEDs. Driving low power red, green, and blue LEDs with an Arduino is trivial. I use external switching transistors with each LED so that I can handle high power LEDs.

On the receiver end, I'm working with two different approaches. The first uses separate phototransistors for red, green, and blue light. I use standard photographic acetate as a filter for each phototransistor. Red, green, and blue transparent film from acetate report covers works just about as well.

I'm also working with color-sensitive light sensors, including the TCS3200-DB color sensor from Parallax. At almost \$60, it's expensive, but it has a built-in array of photodetectors with red, green, and blue filters. It's worth looking at the spec sheet (downloadable from Parallax.com) to get an idea of how they're using the chip. Parallax also sells the TSL230R light-to-frequency converter. As with the TCS3200-DB, the \$6 chip isn't designed for color light communications, but it has potential that's worth exploring.

SparkFun electronics sells an inexpensive TCM600 (\$1.50) light sensor that can be put behind a color acetate filter. As with standard phototransistors, these devices are more sensitive to certain portions of the visible spectrum than others. SparkFun also sells the Avago ADJD-S311-CR999 that has built-in red-green-blue filters (\$5). Unfortunately, you'll have to be skilled at SMT mounting to get at the input and output leads.

Of course, the real work for harnessing broadband light communications is in the software. Checksums and other error-detection mechanisms provision for interference from other visible light transmitters. There's the approach used by most IR remote controllers — that of modulating the beam at about 38 kHz. Take a look at the spec sheet on the IR receiver TSOP85 — available from SparkFun — to get an idea of what's typically involved in light receivers.

Of course, if you're on an unlimited budget, then you could start considering diffraction gratings, prisms, and other commercial-grade tools developed for the fiber optics community. Edmund Scientifics is a good place to look for information and products.

There are obvious technical and behavioral issues that must be addressed before LI-FI becomes ubiquitous. For example, there will be no more tucking your phone in your pocket or purse. You'll have to expose at least part of the phone to light — perhaps as Bluetooth chest-pin communicators akin to those on Star Trek. Then, there are

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times when lights are normally out — when you're sleeping at home or in a plane. There are places and times — the beach or on your bike, for example — where there isn't normally artificial light.

Clearly Li-Fi isn't ready to displace the current WI-FI infrastructure. Perhaps you'll be the experimenter-entrepreneur that works out the kinks and brings LI-FI to market. **NV**

READER FEEDBACK

APOLOGIES TO NUTS & VOLTS READERS

In the November '11 edition of *Nuts & Volts*, we were advertising the new EasyPIC v7 board, and as it was found out, the designers of the ad accidentally placed an incorrect price for the board. Instead of \$139 — as stated in the ad — the price of the board is actually \$149.

We are deeply sorry for this unpleasant mistake, and we want to apologize to everyone who was affected by this.

We will continue to provide only the highest quality products and services with the correct information as we always have.

Sincerely,
mikroElektronika

DEVELOPING OPINIONS

Regarding Bryan Bergeron's November '11 Developing Perspectives column ... I may be tech savy but I'm cooking retarded. I assumed it was an anti-stick mat, but

there was some confusion (as usual) about whether it was silicon or silicone. Silicone gets more hits on Google.

I really like Bergeron's column. His and Fred Eady are the only "must read" articles for me, though I read almost everything — even the ads. Excellent "out of the box" ideas. I'm headed to Goodwill to see if I can find a toaster oven, more for construction than destruction. I've just been wondering how to deal with the collection of boards from old drives, power supplies, and motherboards I have accumulated. Bergeron's suggestion about reusing whole pieces of boards got me thinking.

The floppys and the power supplies look promising as they don't use surface-mount and the traces are big enough to see without a microscope. Reverse-engineering a newer board is a much bigger challenge because the multi-layer PCB's traces are next to impossible to follow. Firing them up and spending a few hours with a good scope might help, but it sounds like too much work for the return.

Keep up the good work.

Steve McChrystal



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■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

MOST COMPLEX GROUND-BASED OBSERVATORY COMES TO LIFE

Last fall, on a 16,000 ft site in northern Chile, the National Radio Astronomy Observatory's Atacama Large Millimeter/Submillimeter Array (ALMA) opened its first set of "eyes" (i.e., millimeter/submillimeter telescopes), and its first glimpse of the universe was AU Microscopii – a star located 33 light years away and only one percent of the age of our Sun. This was done at the behest of ALMA's first customers – Dr. David Wilner of the Harvard-Smithsonian Center for Astrophysics. He noted, "We will use ALMA to image the 'birth ring' of planetesimals that we believe orbits this young star. Only with ALMA can we hope to discover clumps in these dusty asteroid belts, which can be the markers of unseen planets."

Apparently, ALMA is particularly well-suited to locating forming stars which are concealed by dark clouds that are impenetrable by optical telescopes. Shown in the photo (white-blue area) is the generation of super-bright hot stars that formed when the denser centers of the two spirals first collided. The latest stars to light up are ionizing their gas shrouds, making the hydrogen glow bright pink around them. The gas ripped off during the galaxies' first close encounter are shown by the array; here colored blue. ALMA's selection of current star-forming regions in millimeter/submillimeter are shown as orange and yellow.

ALMA will be used to study many other parts of the galaxy and, in fact, the NRAO has already received 900+ requests from around the world to peek at things with it – this even though only about one third of its eventual bank of 66 radio telescopes are in place and operating. As noted by NRAO Director Dr. Fred K. Lo, "We welcome ALMA into NRAO's working suite of state-of-the-art engines of exploration alongside the Very Large Array, the Very Long Baseline Array, and the Green Bank Telescope. With them, and other novel facilities around the world, the astronomical community is entering a golden age of discovery using radio techniques." For a guided tour of the facility, just log onto www.nrao.edu/explorer/alma. ▲



Photo courtesy of NRAO/AUI/NSF
■ Star-forming regions of AU Microscopii as seen by the newly operating Atacama Large Millimeter/Submillimeter Array (ALMA).



Photo courtesy of University of Leicester

■ Test setup for classifying force used in bottle stabbings.

TAKE A STAB AT PRESSURE MEASUREMENT

Well, maybe it isn't advanced astrophysics, but what it lacks in technological awesomeness it makes up for in weirdness. Here in the USA, if we want to do away with Uncle Fred, we tend to take the simple route: We just grab a gun and shoot the SOB. In fact, in the latest federal report (2008) of 14,299 murder victims, a full 66.3 percent (9,484) took a bullet, with a mere 13.3 percent (1,897) cut or stabbed. Things are different in merry old England, however, where stabbing is the most common method of committing murder, with a glass or bottle used in an estimated 3,400 to 5,400 offenses every year. When you smash a Guinness bottle on the bar to create a weapon, each such device is unique in shape and sharpness, so the amount of pressure required to shove it into someone's liver can vary greatly.

Until recently, there have been no systematic studies of how much force is required, as "carrying out reconstructions of glass bottle stabbing incidents can be unreliable and may lead to a misleading approximation of force involved, as glasses and bottles fracture to leave a unique stabbing surface of sharp and blunt points," explained Gary Nolan, a Ph.D. student at the University of Leicester. "This could have major implications for not only those in the field of forensics but also for anyone involved in a stabbing incident. This is alarming from the point of view of victims of such incidents, as such information could influence the outcome of a court case."

However, Gary has tackled the problem and developed a test for classifying the force used in bottle stabbings. "Our study provides the first set of penetration force data for broken glass bottles and illustrates how the consideration of proffering an opinion on force used is different to that of knives." Mr. Nolan added, "Although some bottles have similar

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

ADVANCED TECHNOLOGY CONTINUED

TAKE A STAB AT PRESSURE MEASUREMENT CONTINUED

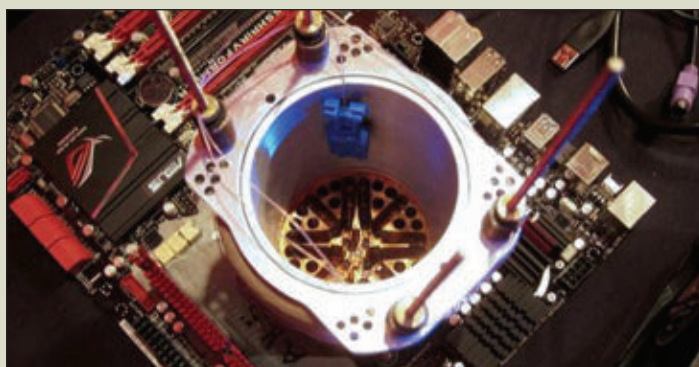
penetration forces to knives, due to the presenting broken glass geometry, most require a much larger amount of force, which suggests that the majority of stabbing incidents involving bottles would require greater force than those involving knives."

Alas, this inquiry seems less aimed at reducing the number of bar fights or convicting criminals than at generating government regulations. Nolan says, "We are now working with the Materials Knowledge Transfer Network and the Institute of Materials, Minerals, and Mining to take the insights from the research into standards for safer pint glasses, and are looking at how we can work with the glass industry to develop new approaches to design of glasses that fracture to create less damaging surfaces." Cheers! ▲

COMPUTERS AND NETWORKING

CPU SETS WORLD CLOCK RECORD

Let's face it. The decades-old battle for microprocessor dominance has always been one sided, with Intel (www.intel.com) and AMD (www.amd.com) being something like Simon and Garfunkle. In both cases, the latter seems to have a place, but you're not quite sure why. But like Art coming up with "Bridge over Troubled Water," AMD recently racked up a space in the Guinness Book of World's Records by topping the "Highest Frequency of a Computer Processor" category with a hugely overclocked version of its eight-core AMD FX desktop processor. Aided by a pair of professional overclockers and liquid nitrogen/liquid helium cooling, the chip reached a speed of 8.429 GHz. The feat was accomplished by virtue of AMD's new Accelerated Processing Unit (APU) technology which combines general-purpose x86 CPU cores with programmable vector processing engines on a single silicon die. According to VP and General Manager Chris Cloran, "Along with world-record frequencies, the AMD FX processor will enable an unrivaled enthusiast PC experience for the money – extreme multi-display gaming, mega-tasking and HD content creation." Before you get too excited and take a whack at the record yourself, beware the fine print: "AMD's product warranty does not cover damages caused by overclocking. Extreme overclocking with liquid helium and liquid nitrogen should only be attempted by professional overclockers." ▲



■ AMD FX processor with liquid cooling.



BIGGER, CHEAPER HDD

Sure, it's the natural evolution of disk storage, but not only does Seagate's new GoFlex® Desk external hard drive break the 4-TB barrier, it lists at only \$249.99. This is particularly timely in the emerging age of multimedia, as 4 TB provides enough space for 2,000+ HD movies and photos of everyone's grandchildren in all 50 states. The standard drive is Windows and Mac OS compatible, and it can be paired with the GoFlex Home Adapter for use as a network drive. Included are automatic file encryption and a USB 3.0 adapter that also works with 2.0 ports; a Mac version will include FireWire 800. The adapter features an illuminated indicator that displays available space on the drive. The drive isn't presently compatible with the emerging Thunderbolt standard, but future GoFlex adapter iterations are expected to handle it. You can get further details or even buy one at www.seagate.com. ▲

■ Seagate's latest GoFlex HDD offers 4TB storage for a paltry \$250.

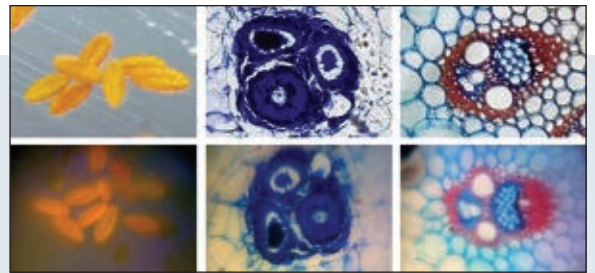
CIRCUITS AND DEVICES

IPHONE FOR MEDICAL IMAGING?

Maybe you're dabbling in the medical field and need a decent microscope to examine things like blood cells. One option would be to log onto **Amazon.com** and get yourself an LW Scientific Medical Microscope at a discount rate of about \$750. If you happen to have an iPhone, however, you can just modify it with a few cheap parts and end up with a rough equivalent, as demonstrated by some resourceful people at the University of California, Davis' Center for Biophotonics Science and Technology (**cbst.ucdavis.edu**). At the October annual meeting of the Optical Society of America (OSA, **www.osa.org**), physicist Sebastian Wachsmann-Hogiu demonstrated how enhanced iPhones might help doctors and nurses diagnose blood diseases in developing nations and transmit real time data for further analysis and diagnosis. It's so simple, that you can probably do it yourself. All you need is a 1 mm dia ball lens inserted into a hole in a rubber sheet and taped over the smartphone's camera. Because the phone's semiconductor sensor includes millions of cells that are only about 1.7 microns across, the microscope can resolve features down to about 1.5 microns. Sure, the images aren't as sharp as what you get from a commercial microscope, but they are sufficient to reveal such conditions as iron deficiency anemia and sickle cell anemia.

The team has also created an iPhone spectrometer that — essentially like a prism — smears out light from an object for analysis. Because atoms and molecules absorb specific wavelengths when exposed to light, one can learn a lot about them by obtaining their chemical signature and studying the obtained spectra. In this case, the team just used a plastic tube with black electrical tape at each end and cut slits in the tape to allow only parallel light beams to enter and exit the tube, thus spreading the light into a spectrum of colors. No word yet on when an iPhone MRI device will appear. ▲

Photo courtesy of UC Davis.



■ Stained images of pollen and plant stems obtained with (top) a commercial microscope and (bottom) an iPhone microscope.



■ OMEGA's UWRG-2 combines RH and temperature measurement in a wireless transmitter. ▲

WIRELESS RH/TEMP TRANSMITTER

If you need to monitor relative humidity and temperature in a facility or equipment, the answer may be the UWRG-2 wireless sensor/transmitter from OMEGA (**www.omega.com**). It measures both conditions in a single unit and — using free software — converts your PC into a multichannel chart recorder or data logger. Signal strength and battery status are also transmitted, and it works with any UWTC wireless receiver or transceiver. You get $\pm 1\%$ accuracy between -17 and 49°C (1.4 to 120°F), $\pm 2.5\%$ RH accuracy between 20 to 80%, and 3.5% accuracy above and below. The transceiver carrier is at ISM 2.4 GHz with 10 mW output power, resulting in a range of up to 120 m (outdoor line of sight) or 40 m (indoor/urban). The units are priced at \$165 standard or \$235 with a NEMA enclosure. ▲

CAN YOU HEAR ME NOW?

Billed as Japan's No. 1 shopping site, Rakuten Global Market (**global.rakuten.com**) claims to offer more than 17 million items from 7,600 participating stores, so you can find just about anything there. As proof, consider the Ear Scope TV which allows you to examine your own globs of earwax on a TV screen — magnified up to 23 times — as you ream out your audio canals. Along with the Ear Scope TV unit, you get the probe with light guide and a protective end cap, a video cable, batteries, and a special ear-adhesive "pita vector," said to be useful for removing "more powdery" wax. And, it's fun for the whole family. As noted in the advertisement, "If the parents while the child's ear to a child TV show, children should have nailed me to sit in Dzuke TV. Big game (earwax) can be viewed with breathless interest the whole family to take a moment (laughs)." It's hard to argue with that. It can be yours for only 168,000 yen (\$2187.77), plus tax and shipping. ▲



■ The Ear Scope TV, available from Rakuten Global Market.

CIRCUITS AND DEVICES CONTINUED

NEW CATALOG AVAILABLE

If you haven't noticed, All Electronics Corp. (www.allelectronics.com) – in the tradition of electronics surplus stores of yore – offers a huge selection of electromechanical and electronic parts, largely at discount prices. The company has released its 96 page 2011 fall catalog, available for free. (Isn't free always good?) All you have to do is log on and sign up or – if you want to save time, trees, and postage – download the PDF version. Such a deal! ▲

INDUSTRY AND THE PROFESSION

CLOUD STORAGE UPSWING PREDICTED

If you're looking for growth areas in the IT market, it might be wise to keep an eye on cloud computing vendors. According to tech analysis firm Gartner, Inc. (www.gartner.com), external controller-based disk storage companies should see industry revenues grow from today's \$417.3 million to \$1.45 billion in 2015 – a nifty 56 percent increase from 2010. To be specific, Gartner defines "external cloud" as "any public, private, or hybrid cloud that is offered by a third-party provider that services multiple customers." This excludes individual organizations' internal data centers. Gartner bases its predictions on the belief that "with the exception of a few extremely large cloud providers, such as Google, Amazon, and Facebook, which have deep pockets for internal R&D to develop their own storage infrastructure with commodity hardware, enterprise-focused external cloud providers will prefer commercial ECB storage technologies over homegrown storage hardware infrastructures." NV

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PICAXE PRIMER

■ BY RON HACKETT

SHARPENING YOUR TOOLS OF CREATIVITY

UPGRADING OUR SERIAL LCD PROJECT

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

In the previous Primer installment, we took a quick look at several of the new features of the recently released M2 line of PICAXE processors, and then explored two of those features in more depth. First, we experimented with the new *timeout* option for the *serrxd* and *serin* commands which now enables us to specify how long (in milliseconds) an M2 program should wait at a *serrxd* or *serin* command before “giving up” and moving on if no data is received. As a result, we no longer need to know exactly how many serial bytes will be received. As long as we provide more than enough variables in which to store the incoming serial data, the new *timeout* option will enable our program to “move on” to processing the data, no matter how many bytes are actually received.

The second feature we discussed is the ability to use *indirect addressing* to access the new M2-class storage variable area of memory. Indirect addressing is a very fast and powerful approach to storing and retrieving data values, so it's well suited for manipulating the data that we want to display on an LCD. This month, we're going to apply what we learned in the previous installment to upgrade the LCD program that we originally developed back in the June and August '09 columns. When we're finished, our serial LCD will be able to handle high speed, variable length serial input without missing a character.

Before we get started with this month's project, there are two web-related announcements I would like to make. First, T & L Publications recently unveiled a new set of forums for *Nuts & Volts* and *SERVO Magazine* so that readers and writers can interact, so there's one for the PICAXE Primer. You can access all the new forums at <http://forum.nutsvolts.com>. While you're there, stop by the PICAXE Primer Forum and let me know how you're doing with your serial LCD upgrade. If you have a question about our upgrade project (or any PICAXE project for that matter), the PICAXE Primer Forum will be a good place to

post it. I hope we'll see you there!

My second web-related announcement is that Revolution Education recently unveiled a complete redesign of the PICAXE website, including a new URL (www.picaxe.com). If you haven't yet visited the new site, you may want to check it out. It includes a wealth of well-organized PICAXE-related information.

Okay, let's get down to business!

UNDERSTANDING THE M2-CLASS MEMORY AREAS

There are three different memory areas in all PICAXE processors. We're going to focus on the details for the M2 processors, but if you're also interested in the memory structure of the X2 processors, see “Understanding the PICAXE Memory” in Section 1 of the PICAXE manual. **Figure 1** presents a summary of the M2-class memory features; let's review the salient points. First, all M2 processors contain 2,048 bytes of non-volatile (Flash) program

■ FIGURE 1. M2-class memory summary.

	08M2	14M2	18M2	20M2
Program Memory (Non-volatile)	2048	2048	2048	2048
Table Mem. (part of prog. mem.)	0	512	0	512
Data Memory (Non-volatile)	256*	256	256*	256
Total Variable Memory (RAM)	128	512	256	512
General Purpose Variables	28	28	28	28
Storage Variables	100	484	228	484
"Safe" Storage Locations	(28-127)	(28-511)	(28-255)	(28-511)

* Shared with Program Memory

memory. That means that a downloaded program isn't lost when power is removed from the processor; the next time power is applied, the downloaded program will automatically start to run.

On the 14M2 and 20M2 processors, a maximum of 512 bytes of the program memory can be set aside as a lookup table. This feature is especially useful for storing strings for display on an LCD, so naturally we'll be experimenting with it this month. Unfortunately, there's no table storage on the 08M2 and 18M2 processors.

All M2 processors also contain 256 bytes of non-volatile data storage. On the 14M2 and 20M2, this is an entirely separate area of memory; on the 08M2 and 18M2, it's part of the program memory. As a result, on the 08M2 and 18M2 every data byte that we store decreases the available program memory by a byte. Similarly to table storage, data storage can also be very useful with LCDs, so we'll be taking a look at it as well this month.

The variable memory area on all PICAXE processors is located in random-access memory (RAM), so unlike program and data memory, variable memory is volatile. When you turn off the power to a PICAXE processor, all the values that were stored in the variable memory area are lost. The next time you apply power, all the variables will be re-initialized to 0. In spite of this limitation — as we will soon see — the variable memory area can also be extremely useful for working with LCDs.

As shown in **Figure 1**, the variable memory area can contain two different types of variables: the 28 general-purpose (GP) variables (*b0* through *b27*) included in all M2 processors, and as many as 484 storage variables. As you know, the GP variables are extremely flexible; they can be renamed by using a *symbol* instruction, and they can be used in any command that supports variables — including computations.

Storage variables have neither of these capabilities; they can't be renamed and they can't be used in mathematical calculations. We can

■ **FIGURE 2.** Breadboard setup, serial LCD upgrade.

only write a value to a storage location (e.g., the statement *poke 100, 25* writes the value 25 to storage location 100) or read its value (e.g., the statement *peek 50, b0* copies the value stored at location 50 into the GP variable *b0*).

Nevertheless, the storage variables may be the most powerful mechanism we have for manipulating string data for use with LCDs, primarily because of their ability to be addressed indirectly. (You know we were headed there, didn't you!)

One final point is worth making before we get to our LCD upgrade. The values of the 28 GP variables are stored at locations 0 through 27 in the variable memory. We can write a value to any location in the variable memory, either directly or indirectly. For example, the following two code snippets each write the value 2 to storage location 5:

- **Direct addressing:**

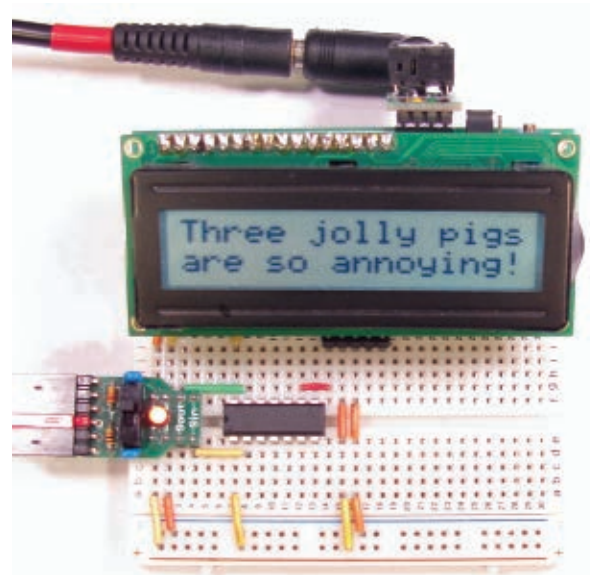
```
poke 5, 2
```

- **Indirect addressing:**

```
bptr = 5
@bptr = 2
```

However, the problem is that in both snippets we have changed the value of GP variable *b5* which may not be what we intended to do! Especially when you are first experimenting with using the variable memory area, I would recommend that you avoid locations 0 through 27 completely. If you want to change the value of GP variable *b5*, just write *b5 = 2* or, if you have previously written *symbol myVar = b5*, you can also write *myVar = 2*.

Of course, when you feel comfortable manipulating the values in the variable memory area, there may be times when you have a good reason to ignore the rule. For



example, if for some reason you wanted to re-initialize all 28 GP variables to 0, you could use the following code snippet:

```
for bptr = 0 to 27
  @bptr = 0
next bptr
```

However, in each of the programs we're about to explore, I'll obey my own rule and keep our data within the "safe" storage locations listed in **Figure 1**.

UPGRADING OUR SERIAL LCD PROJECT

Before we discuss the software for our LCD upgrade project, let's set up the necessary hardware. We'll need two processors for our experiments this month: a 14M2 to install on the serial LCD board, and another processor to send serial data to the upgraded LCD for testing. I used a second 14M2, but you can also use a 20M2 (or any X2 processor) because those processors all support the *table* command that we will use in one of our experiments.

Figure 2 presents the breadboard circuit that I used, but feel free to modify it to suit your needs and the processor you are using. As you can see, I am using two programming cables. A re-configured FTDI USB-to-

serial cable (see the June '10 Primer) is connected to my AxMate-FT programming adapter for powering the project and programming the 14M2 that will send serial data to the LCD. An AXE027 USB-to-serial cable is connected to the LCD board via the same adapter we used back in the original project (see the June '09 Primer). Of course, you can modify this setup to suit your needs. If you don't have an AxMate setup, you can use whatever 5V power supply you have on hand. If you only have one programming cable, you can just move it back and forth between the two processors as necessary. As you can also see in **Figure 2**, I'm using pin B.4 as my serial output pin. If you use a different pin, you will need to modify our test programs accordingly.

When you have completed your breadboard setup, we're ready to move on to the software portion of the project. The first thing we need to do is to modify our original LCD driver software so that it includes the techniques we developed in the *SerrxdFast14M2.bas* program that we discussed last time. The original LCD driver program was fairly involved, mainly because of my determination to include custom characters with true descenders. (Sorry about that!) Since we worked on the original project so long ago, you may not remember many of the details of the final driver program (I certainly didn't), so you may want to re-read the June and August '09 installments to refresh your memory.

Fortunately, we don't need to make many changes to implement our upgrade. As usual, the upgraded software (*LCD16x2-CustCharDriver14M2.bas*) is available for downloading at the article link. While you're there, also download the other three programs we'll be using this month. You may want to print out a copy of each program for reference during the following discussion.

When you have done that, you will see that some of the comments in each program end with a numbered "footnote" in brackets. In the discussion, I will use the same numbering system to make it clear

which program line is currently being referenced.

Program 1 (*LCD16x2-CustCharDriver14M2.bas*): If you read through the main program loop in the upgraded driver software, you will see that we have essentially replicated the approach we used last time in the *SerrxdFast14M2.bas* program. The following are more complete footnotes for the program:

1. We're taking advantage of the 14M2's high speed capabilities, and are running the program as fast as possible so that our LCD will be able to keep up with any serial transmissions it receives.

2. I included the "Ready to Receive Data" section of the program so that you can see it's running correctly. However, displaying the "ready" message does take a couple of seconds every time the LCD is powered on. So, after you're sure everything is working correctly, you may want to delete this entire section (as well as the *data 64* and *data 80* statements earlier in the program) and re-install the driver on the LCD board.

3. Here, we're following the "rule" I suggested earlier, and initializing the byte pointer to 28 so that we don't overwrite any of the GP variables at locations 0 to 27.

4. This command is simpler than the bug fix we used in the previous column because the latest version of the Programming Editor (version 5.4.2) has corrected the bug. This *serin* command doesn't include a *timeout*, so it is *blocking*. In other words, the program will wait at this instruction until it receives the first serial byte. **Important:** Be sure to upgrade to version 5.4.2 of ProgEdit before downloading the new driver software to your 14M2. Also, note that we're using 9600 baud for our serial interface. This is because all current PICAXE processors are capable of at least that speed. If you want to send data to the LCD from an older M-class processor, you can run that processor at 8 MHz and use its *serout* pin and the *sertxd* command which will give you 9600 baud.

5. As we discussed the last time, this instruction may look strange due to its unusual length, but it's the fastest way to receive all the data. We have allowed for a total of 41 bytes (one in the blocking *serin* statement and 40 in the non-blocking *serin* statement). That should be more than enough to fill both lines of the LCD, including a few commands mixed in with the 32 characters, as necessary.

6. Here, we again tack on a final value of "0" as an "end of transmission" marker.

When you have studied the updated LCD driver software and understand how it works, download it to the 14M2 processor on the LCD board. You should see the "ready" message displayed for a couple of seconds, and then the display will clear. If that doesn't happen, you will need to troubleshoot your setup. If you can't get it working properly, email me (Ron@JRHackett.net) and I'll try to help.

Program 2 (*SeroutToLCDdemo.bas*): This program – which we're going to download to the 14M2 on the breadboard – is just a simple demonstration of a few of the ways that serial data can be sent to the LCD. The program is simple and thoroughly commented, so we don't need to discuss it here. Hopefully, it will show you how flexible the upgraded LCD has become. Using only one *serout* command, we can now accomplish the following:

- **Fill one line of the display**
 - (see program comment 1).
- **Fill both lines of the display**
 - (see program comments 3 and 5).
- **Update text in a single location**
 - (see program comment 2).
- **Update text in multiple, disjointed locations**
 - (see program comment 4).
- **Create special effects**
 - (see program comment 6).

Download *SeroutToLCDdemo.bas* to the 14M2 on your breadboard

and try it out. When you get tired of watching the same sequence of displays, you may want to add your own *serout* commands to see what you can accomplish with the upgraded display.

Program 3

(SeroutToLCDtable.bas): When the 14M2 and 20M2 processors were first released, I was eager to experiment with their *table* and *tablecopy* commands. The *table* command has been around for a while; the X1 and X2 processors also support it. *Tablecopy*, however, is a new command; only the 14M2 and 20M2 processors support it. *Tablecopy* is the command that really interested me. It can be used to copy all or part of the table data to the storage variable area in the processor. For example, consider the following code snippet:

```
table 28, ("Hello world!")
tablecopy 28,12
```

The *table* statement embeds the 12-character string in the program memory area (starting at location 28) and then the *tablecopy* statement automatically copies the string to the storage variable area. The first parameter of the *tablecopy* statement (28) specifies the starting location for the copying, and the second parameter (12) specifies the number of bytes that will be copied (in this case, the entire string). Immediately after the two statements have executed, "Hello world!" has been stored at locations 28 through 39 in the storage variable area. At this point, you're probably asking yourself "Why bother?" The answer is that now we can use indirect addressing to access the data and send it to our serial LCD. (Aren't you glad you asked?)

If you read through the copy of *SeroutToLCDtable.bas* that you downloaded, you can see that it's fairly straightforward; there are just a couple of aspects of it that I want to clarify:

1. Here, we're again following

my "rule" by not using storage locations 0 through 27. Each *table* instruction contains 17 bytes of data. The first byte is a command byte that specifies the LCD line on which the data is to be displayed (128 = line 1, and 192 = line 2); the remaining 16 data bytes are the string that is to be displayed on the specified line.

2. The *for/next* loop executes four times with index values of 28, 45, 62, and 79. Each time through the loop, *bptr* is initialized to one of these four locations which each contain the command byte for the data that is currently being accessed. The *if/then* statement tests *@bptr* (which is the value "pointed to" by *bptr*). If *@bptr* is 128, we're going to be displaying the data on line 1, so the LCD is cleared just before we actually display the line of text.

3. The *print* subroutine is a simple loop that sends the 17 bytes of data to the LCD.

Before you download *SeroutToLCDtable.bas* to the 14M2 processor on your breadboard, I want to give you a "heads-up." The download is going to take much longer than usual. (My download takes more than 50 seconds!) After you have tested the program and have a clear understanding of how it functions, we'll discuss the download issue, and experiment with one way of avoiding it.

The first program that I wrote to experiment with *table* and *tablecopy* was much simpler than the final *SeroutToLCDtable.bas* program, but it also took more than 50 seconds to download to my 14M2. I tried several modifications to the program, but no matter what I did, the problem persisted. Hoping that someone else might have encountered the same issue, I posted the details on the PICAXE forum. It wasn't long before there was a reply from "Hippy," one member of the RevEd's technical support team. As usual, Hippy's response was very informative. He explained that the long download times for 14M2 (and 20M2) programs that include *table* statements are the result of the

internal memory layout of those processors.

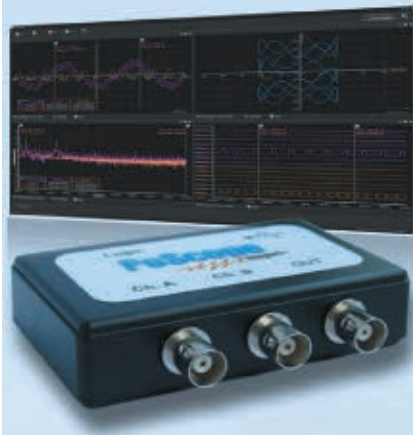
Hippy also suggested switching to an X2-class processor because the X2 *table* command doesn't slow down the program downloads. However, I think it's important to be able to use any current PICAXE processor with our upgraded LCD display, so I was determined to find a way of doing what I wanted (using *@bptrinc* and indirect addressing) without using the *table* command. The solution I came up with was to replace the *table* commands with *data* commands. Since there is no PICAXE *datacopy* command, I had to do that part in software, but that's really easy to do.

Program 4

(SeroutToLCDdata.bas): Our final program this month demonstrates the use of the *data* command to store and send the same data to our LCD as we just did with the *table* command in *SeroutToLCDtable.bas*. We'll discuss the pros and cons of these two approaches after we explore and understand the "data-based" alternative. Take a look at your printout of the *SeroutToLCDtable.bas* program; you'll see that it's very similar to the "table-based" program we just discussed, so let's just focus on the differences.

1. As you can see, the program includes a "commented-out" *#no_data* directive. After the first download of the program to your 14M2, you can "un-comment" this directive so that the *data* statements aren't downloaded each time you run the program. As you know, EEPROM storage is non-volatile; even if you power-down the 14M2, the correct data values will still be retained the next time you power-up. Including the *#no_data* directive in subsequent downloads will also eliminate the second pass the compiler makes during the download process, speeding things up a bit. Of course, if you need to change any of your *data* statements as you are working on a project, you would need to comment-out the *#no_data* statement

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temporarily to download the new data to your processor.

2. In the previous program, we started the table storage at location 28 to avoid any possible conflicts with the GP variables which are stored at locations 0 through 27. This time, however, we're storing our data beginning at location 0 in the EEPROM memory area. As we're about to see in the next comment, this won't be a problem.

3. In effect, this *for/next* loop accomplishes the same thing that the *tablecopy* statement did for the table data; it copies the data into the storage area RAM. Each time through the loop, the *bptr* variable is set equal to the current value of *index*, plus 28. That way, we avoid storing any data in locations 0 through 27 which could create problems with the GP variables in a program. The *read* statement reads each data byte and places it in the *@bptr* variable which automatically stores the value at the location pointed to by *bptr*.

4. In the second *for/next* loop, we're using the same *start* and *end* parameters; the *step 17* parameter results in *index* being set to 0, 17, 34, and 51 for the four passes through the loop. However, each time through the loop, *bptr* is set equal to the value of *index* plus 28, so *bptr* assumes values of 28, 45, 62, and 79. Those four locations are where we previously stored the first byte (the command byte) of each *data* statement. Next, the *if/then* statement in the loop checks to see if we're about to print on line 1 of the LCD (command byte = 128). If so, the LCD screen is cleared. Finally, the 17-byte data string is sent to the LCD for display.

When you're ready, download *SeroutToLCDdata.bas* to the 14M2 on your breadboard setup. The download should be much faster than that of the *SeroutToLCDtable.bas* program; mine took about 10 seconds — a welcomed improvement! The sequence of the text on the LCD should be identical to what you observed with the previous program. The only purpose in switching from *table* statements to

data statements was to make the download time much faster.

However, if you refer back to **Figure 1**, you can see that the 08M2 and 18M2 processors have 256 bytes of data memory, but no table memory. Therefore, *data* statements can be used with any M2 or X2 processor, while *table* statements are only usable with the 14M2, 20M2, or any X2 processor, which is certainly something to keep in mind when you are designing a project that includes a serial LCD display. Also, the table version filled 185 bytes of program memory, but the data version only requires 78 bytes. I don't know why the difference is so big, but it's another clear advantage of the data version.

That's all for this month's Primer, but we certainly haven't exhausted the possibilities for efficient and flexible ways of sending data to our upgraded serial LCD. You may want to experiment with combining the approaches of our demo program and either the table (if you have the patience for the download times involved) or the data approach. Don't forget that it's not necessary to send a full line every time. You can certainly use either *table* or *data* statements to target specific locations on the LCD screen as we did in the demo program.

Also, in addition to sending text strings, you can update variable values in real time just by preceding the variable name with the “#” character, as we have done in the past. For example, *serout txPin,N9600_8,(133,#myVar)* would print the current value of *myVar*, starting at position 6 of line 1 on the LCD. Have fun!

WHAT'S NEXT?

To tell you the truth, I don't know! I have been so engrossed in our LCD upgrade project that I haven't stopped to think about it yet. If you have any suggestions about what you would like to see covered in this column, post them on the N&V Primer forum. In the meantime, I'll put on my thinking cap and see what I can come up with.

See you next time. **NV**



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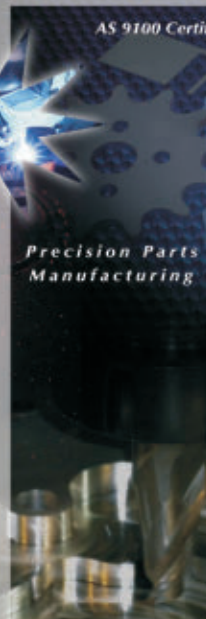
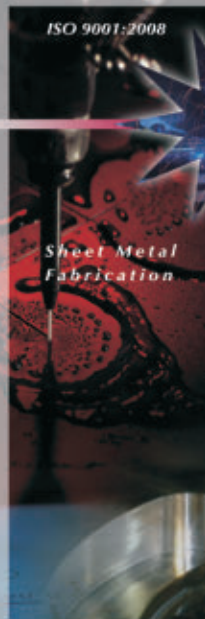
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Simulates the sound of a vintage steam engine locomotive and whistle! Also provides variable "engine speed" as well as volume, and at the touch of a button the steam whistle blows! Includes speaker. Runs on a standard 9V battery.



- MK134 Steam Engine & Whistle Kit** \$11.95

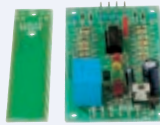
Laser Trip Sensor Alarm

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

Liquid Level Controller

Not just an alarm, but gives you a LED display of low, middle, or high levels! You can also set it to sound an alarm at the high or low condition. Provides a 2A 240VAC rated relay output. Runs on 12-14VAC or 16-18VDC.



- K2639 Liquid Level Controller Kit** \$21.95

The Holiday Spotlight!

LED Animated Santa

This animated Santa and reindeer display has been our most popular holiday display for years! It contains a whopping 126 dazzling colored LEDs which make it a great holiday sign that is guaranteed to draw attention!



LED animated motion makes it come alive. Runs on standard 9V battery or 9-12VDC external power supply. Dazzle your friends this great display!

- MK116 LED Animated Santa Kit** \$16.95

LED Christmas Tree

Electronic Christmas tree features 134 bright colored LEDs in the shape of a gorgeous holiday Christmas tree. Includes 18 random flashing blinking "candles" on the PC board! Runs on a 9V battery or external 9-12VDC power supply.



- MK117 LED Christmas Tree Kit** \$18.95

LED Animated Holiday Bell

This PC board holiday bell is animated to simulate a bell swinging back and forth! 84 bright colored LEDs will dazzle you with holiday cheer! Includes an on/off switch. Runs on 9V.



- MK122 LED Animated Bell Kit** \$16.95

3D LED Christmas Tree

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



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

SMT LED Christmas Tree

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



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

SMT LED Smiley Face

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



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

LED Traffic Signal

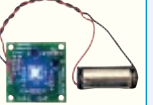
Not exactly a holiday theme, a real attention getter for this time of the season! Impress your friends with this neat 4-way traffic signal! Operates just like a standard signal, and features adjustable delay. Red, yellow, and green LEDs are used just like the real thing! Runs on 9V battery.



- MK131 LED Traffic Signal Kit** \$7.95

LED Switcher Blinkiey

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



- LSW1 LED Switcher Blinkiey Kit** \$14.95



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Collectors come across some great deals on antique battery-powered radios, but how to power them is a real problem. Many classic radios operated on batteries only, and in many cases a series of three batteries for each radio were required!



The new ABCE1 Battery Eliminator gives you an easy way to replace all these batteries with a simple household AC power connection and resurrect your vintage antique radios! Provides "A" filament, "B" plate, and "C" control grid supplies, which are all isolated from each other. Complete with aluminum case. Runs on 110-240VAC.

ABCE1 Vintage Radio Battery Elim Kit \$199.95

Passive Aircraft Monitor

PATENTED!

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



ABM1 Passive Aircraft Receiver Kit \$89.95

RF Preamp

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

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

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

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

Tri-Field Meter Kit

THE GHOST DETECTOR!

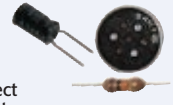
"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.



TFM3C Tri-Field Meter Kit \$74.95

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

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The third generation of Ramsey digital voice storage kits! We started with the latest digital voice storage technology. It provides up to 8 minutes of digital storage at a frequency response up to 3.5 KHz. (Total message time and frequency response is dependant on selected internal sampling rate.) Once recorded, messages are available for playback on-demand or automatic continuous looping. Standard RCA unbalanced line level output is provided for easy connection to any amplifier, amplified speaker, mixer, or sound system. In addition, a standard 4-8 ohm speaker output is provided to directly drive a monitor speaker. Can be remote controlled via 3-wire BCD with our interface options. Check www.ramseykits.com for all options!



DVMS8 Digital Voice Message 8Ch Kit \$99.95
DVMS8WT Assembled DVMS8 \$149.95

Voice Activated Switch

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



VS1 Voice Switch Kit \$9.95

Touch Switch

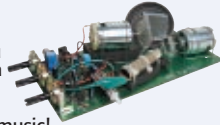
Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.



TS1 Touch Switch Kit \$9.95

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

USB DMX Interface

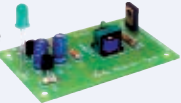
Control DMX fixtures with your PC via USB! Controls up to 512 DMX channels each with 256 different levels! Uses standard XLR cables. Multiple fixtures can be simply daisy chained. Includes Light Player software for easy control. Runs on USB or 9V power.



K8062 USB DMX Interface Controller Kit \$67.95

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

Electronic Watch Dog

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



K2655 Electronic Watch Dog Kit \$39.95

Sniff-It RF Detector Probe

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



RF1 Sniff-It RF Detector Probe Kit \$27.95

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Q&A

WHAT'S UP:

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

- ✓ Sine Wave Modulator
- ✓ Remote Ammeter
- ✓ Surface-Mount Adapter

■ 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**

COMPUTER FAULT FINDER

Q I repair computers, including laptops and desktops. My question is on how to build a fault finder for laptop motherboards. Instead of replacing the system board, I want to repair and rehabilitate the faulty component whether it is a capacitor, resistor, or video or power/charging issue. For instance, when you push the power button, some of the LED lights may flash but nothing powers up.

— Mike

A Many years ago, I worked in computer repair and we used a device made by Huntron which displayed a Lissajous pattern when you probed a circuit. The circuit was not powered; it just depended on the impedance at that point. By comparing the pattern of a defective circuit with that of a known good circuit, you could find the defective part and did not need to know how it worked.

The principle is quite simple, so I built one; see **Figure 1**. The signal at the vertical input is the voltage (always 12V), but the signal at the

horizontal input is related to the impedance.

If there were a sufficient number of boards to check, you could make a "bed of nails" probe with computer control to quickly troubleshoot. The manual process is too tedious for me, but it works.

DEER REPELLANT CIRCUIT

Q First of all, thank you for the diagram you created called the PIR-controlled IR illuminator. However, I have another request which also involves two PIR modules and an amplified barking module that I'd like to build in order to repel deer from my garden.

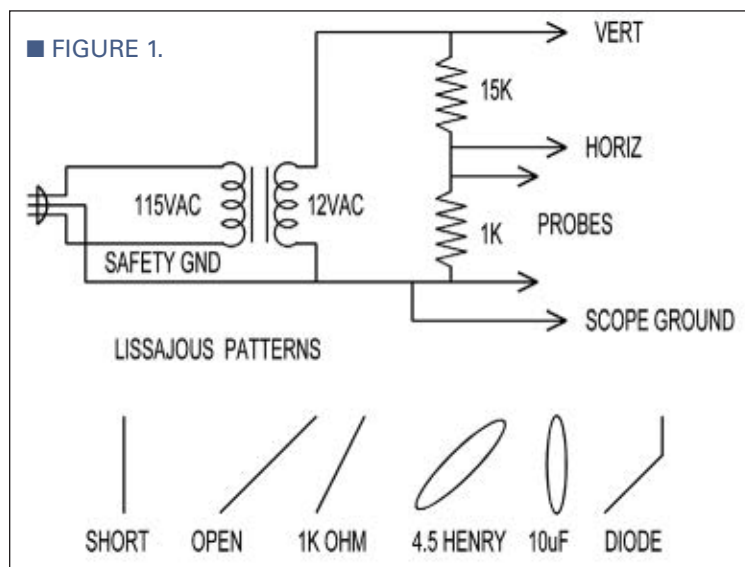
I'd like to add (without basically

modifying) the two modules I bought from **QKits.com** (dog barking module #FK207 and two watt amp #FK674) and two PIR modules purchased from **Parallax.com** (#555-28027) in order to turn on the amplified barking module for at least one minute as soon as heat/movement is detected by either one of the two PIR modules (no precise time required), then turn the unit off after about a minute. I'd like the PIRs to be connected in parallel to independently turn the unit on.

I'd like to use just one power supply (please specify the best power supply in terms of voltage and current) for the amplified barking modules, as well as the two PIRs.

P.S. I've tried the solar ultrasonic 'deer repellent' which probably scares only ghosts, *not* deer!

— Don



A I answered a similar question some time ago (November '08, page 29), but to answer your question, see **Figure 2** for the connections of the two PIR modules and the barking dog module.

The barking dog module works on three to six volts so, since you have to have a five volt regulator for the PIR modules, you might as well run the barking dog module at five volts

also. The PIR modules are connected to pin 3 of the voice IC through diodes which provide the OR function. You don't need to install any jumpers; the barking will continue as long as there are warm bodies moving. Taking the audio output from pin 5 of the voice

IC is good and you might remove TR1 — the output transistor — to save power since you are not using the speaker.

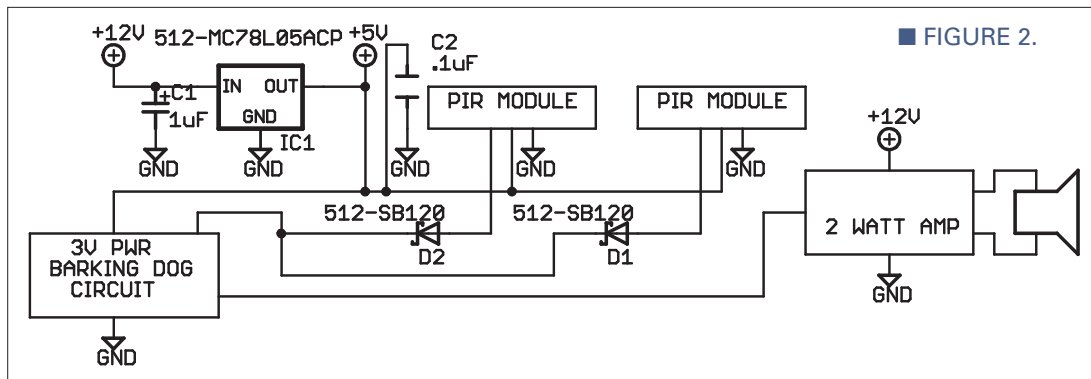
The 12 volt power supply should be rated at two amps if you are running the power amp at maximum volume. The recommended speaker for the power amp is eight ohms.

TELEPHONE REMOTE CONTROL

Q I want to open the door to my work room by calling a phone number on my internal phone system. I bought an electronic door lock which operates on 12 VAC. How can I do that circuit?

— Selahattin SADOGLU

A The circuit in **Figure 3** is powered from the DC of the telephone line through R1 and D1. The output of IC1 is normally low because the bias from R5 and R6 is higher than the voltage on the positive input. The ring signal — which is 80 or 90 VAC — is enough to lift the positive input higher than the bias, causing the output to go high. Positive feedback through R2 latches the output high, and you have to press the reset switch to re-lock the door and put the phone on hook. I don't think the current drawn by the circuit will be enough to keep the phone off hook, but if I am wrong, you may want to use an external six volt supply.



■ FIGURE 2.

SINE WAVE MODULATOR

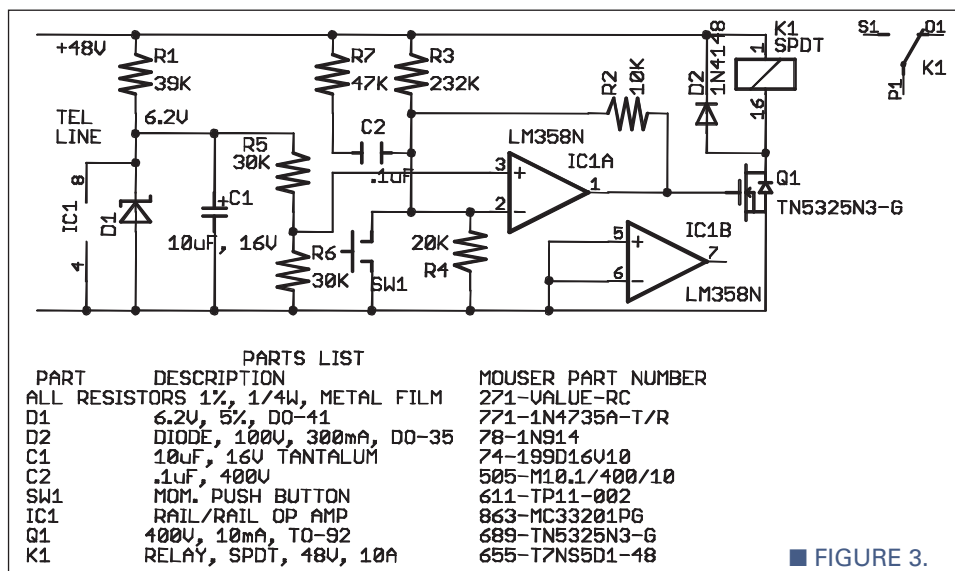
Q Could I use your expertise in designing a circuit to modulate a 455 kHz signal? The 455 kHz signal is generated from a CD4093, divided by 1024 with CD4040. The CD4040 gives me a good frequency count with a 4-1/2 digit counter. The resulting 444 Hz is then fed into a CD4011 for a 0/+6 and 0-6 square wave. The square waves are then fed through an RC network for a fair sine wave. The objective is to modulate the 455 kHz signal with the 222 Hz signal (here's the hard part) without distorting the carrier wave. Through hole devices are preferred. The power supply is +6/0/-6 volts. Any ideas will be greatly appreciated.

— Weldon Thorp

A Sine wave modulation is really easy, just use the sine wave as power for the carrier amplifier and see **Figure 4**. The resultant signal will have a DC component which can be eliminated by a coupling capacitor.

TIMER

Q I need to build a summing timer of some sort that will tell me the time it takes to stop rotation of a shaft. I was thinking of using a 1,200 PPR (pulses per revolution) encoder on the end of the shaft. The timer would have to measure the time between pulses and sum them until there are no more pulses. When power is stopped to the shaft, the timer will receive a start signal to start timing. The distance between pulses would be timed and the time added together until the pulses stop; the total time would be displayed so that



■ FIGURE 3.

the time to stop rotation can be determined.

I am a plant electrician; we have machines that have light curtains to stop the machine if something breaks the curtain. There is a regulation that the machine must stop before an object moving at a velocity of 65 in/sec breaks the curtain and hits the machine. A typical setup would be 15 in from the light curtain to the machine; therefore .231 sec to stop the machine. That is why I need to know the time it takes to stop.

One sec would probably be the most time I would be dealing with.

I'm interested in solving this problem, so any help would be appreciated.

— Ken Brown

A What you suggest is rather complicated; it's much easier to start a free-running timer (stop watch) and stop it when the shaft stops turning. The hard part is determining that the shaft has stopped. If the friction is low, it will keep turning slower and slower. The timing system will have to measure the rate that the shaft is slowing and estimate when the next pulse is due. If the pulse does not happen in a time window, the assumption will be that it has stopped.

IR REMOTE CONTROL

Q I want to add a remote control to a project I'm building. I would like to use a four channel IR remote control using 5 VDC for the power supply.

I found the remote receiver I would like to use but the trouble is it uses latched TTL for the four channel outputs.

The project I'm building uses tactile switches for control, but I would like to control the unit remotely without using relays.

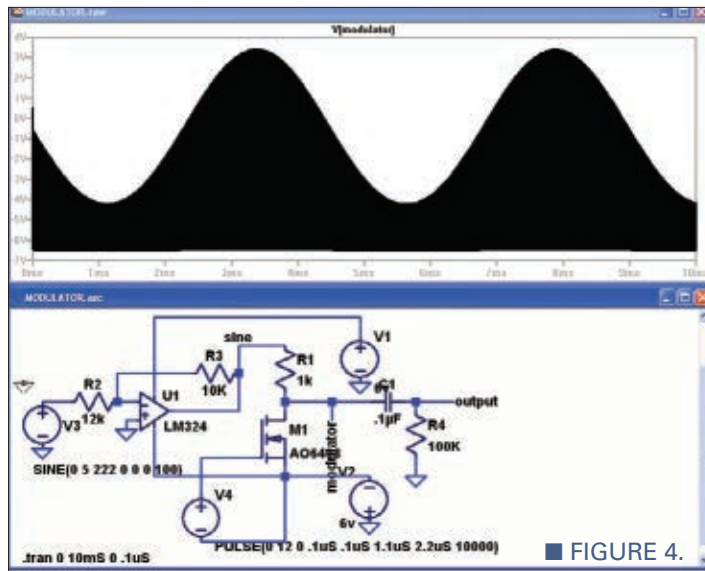


FIGURE 4.

Is there a simple transistor circuit that I can use to replace the tactile switches?

Or, am I still better off using five volt relays?

— Jeff Miller

A Since you have TTL to drive it, I recommend a solid-state relay (Mouser 782-VO1400AEFTR). It handles AC or DC, and turns on with 3 mA. TTL pulls down better than up, so connect 1K from the LED anode to +5V and the TTL output to the LED cathode. This relay is less than 1/4 inch square and is surface-mount but easily solderable. You can find a thru hole equivalent at Mouser; 769-AQY212GH is an example.

REMOTE AMMETER

Q I'm using 100:5 ratio current transformers (CT) to monitor incoming AC utility power and generator load when the power is out. The four CTs are only accurate when they are presented with a .4 ohm load or less on the secondary. The ammeters I use are .4 ohms which means if I want them to be at a remote location I would have to use something like number 8 wire. I'm looking for a circuit that can act as a buffer amplifier for these CTs. It needs to have in input impedance less than .4 ohms, accept 0-5 amps AC 60 Hz,

and output the same signal with the ability to drive at least one or two ohms.

— John Spangler

A I believe back-to-back transformers will solve your problem. Mouser #546-266M5 can be configured for 2.5 VAC to 234 VAC. It is rated six amps at 2.5V, so the current at the 234V secondary would be 64 mA. The same transformer at the remote site will step the current back up. However, you

could use a 12 VAC transformer — #546-266K12 (wiring the windings in series), adjust the load for five volts out with five amps in, and read the current with a voltmeter. I figure the load to be 4.8 ohms, five watts. The advantage of using the 12V transformer is that the load presented to the current transformer will be less than .4 ohms; you can compensate for losses by adjusting the variable load.

BASIC COMPILER WANTED

Q In the August '11 issue on page 23, there is "Basic" code for a PIC. I have been programming these in assembly language, using Microchip's assembler.

I haven't seen any project done in assembly, so I am looking for a cheap or free Basic compiler, like the one in the August LED flasher circuit article.

— Gregg Reber

A A Google search for "free PIC Basic compiler" brought up GCBASIC which you should check out at <http://gcbasic.sourceforge.net/download.html>. Many compilers have free versions which are limited in size of program or features. The program that I use has

MAILBAG

Dear Russell: Re: Solar Controller, August '11, page 22.

My son says we are going to get six more solar panels from Harbor Freight and he is going to take the two off of my RV and connect them all together. Of course, he claims he knows nothing about electricity or electronics but that is what he plans to do.

So, what modifications can I make to the controller you sent me the schematic for and how many of what kind of batteries will I need for eight Harbor Freight solar panels to be off the grid?

— Denis Kellogg

Response: If the panels are all 15 watt, the output can be 10 amps. So, I recommend changing the power transistor and diode; transistor 512-FQPF30N06L and

diode 511-STPS40M100CT.

If you are planning to use this for emergency power for the house, you should plan on at least 2 KW for 10 hours (20,000 W-H). I recommend deep cycle type batteries which will have screw posts and wing nuts, as well as standard automotive posts. If you buy 100 AH batteries, you will need 170 of them (120 watts each). I think a gasoline powered generator will be more economical, and you won't have to replace it after five to 10 years.

Dear Russell: Re: Comb Generator Request, September '11, page 22.

In your answer to the first question [Comb Generator], the schematic refers to a UHF-N device. What is the source of this device?

The online datasheet catalog doesn't recognize it. Where else

should I look or is this sheer unobtainium?

— Ronald G. Hand

Response: There wasn't a part number associated with that SPICE model, but Mouser #771-BFR540-T/R should be applicable (9 GHz, SOT-23, \$0.90).

Dear Russell: Re: DSL Carrier Detector, September '11, page 23.

You might have a marketable product with the DSL detector circuit. At my age (75+), I'm too shaky to build it myself, and I'm sure there are others out there that would buy such a device if it was available at a reasonable price. If you decide to build one, put me on your list.

— David Schoepf

Response: With my schedule, I am not going to have time. If anyone wants to make it, go for it.

an experimenter version for \$49.95 that is limited to 28-pin devices (www.csmicrosystems.com/products/270-picbasic-pro-compiler-3x-experimenter-edition.aspx).

SURFACE-MOUNT ADAPTER

Q I recently obtained a few samples of an IC I wanted to experiment with; it is so small I can hardly see the contacts without my reading glasses. It is about 1/8" square with eight contacts. Is there any way I can use these? I couldn't possibly solder them. Does any business sell small printed circuit boards to which these could be attached? Is there any retail business that would mount these for me?

— Bill Brown

A I found a company that does exactly what you want: www.proto-advantage.com. They have a kit with wire-wrap pins for an eight-pin SOIC for \$3.67. For an additional \$6 plus the part, they will order the part from Digi-Key and mount it on the board. The wire-wrap pin is .025" square and is too large to plug into a breadboard. For an additional \$1, .018" round pins can be supplied. I suspect that you could send the part to be mounted instead of them ordering it from Digi-Key. The adapter that you are interested in is at www.proto-advantage.com/store/product_info.php?products_id=2200001.

Good luck with your project. **NV**

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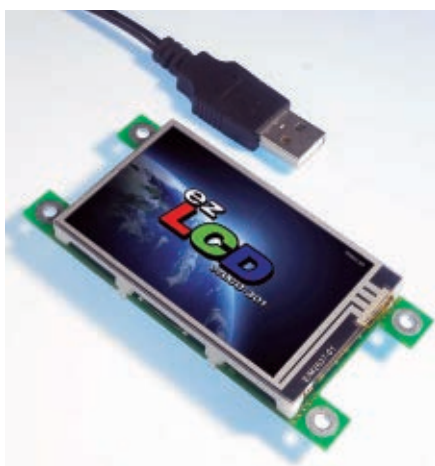
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EarthLCD announces the immediate availability of their new ezLCD-301 smart touch LCD module – the first of a planned series of improved, third generation ezLCD devices. Helping engineers minimize development time and hardware costs while speeding time to market for products requiring a display, the ezLCD-301 provides an effective solution as a graphical user interface (GUI). Its all-in-one modular design unites a color LCD, touch screen, control electronics, memory, and I/O, with an easy-to-use USB programmable firmware environment.

Serial terminal software (included) and the EarthSEMP language (Simple Embedded Macro Programming Language) allows users to quickly customize macros, graphical objects, fonts, images, and interfaces, shortening the design cycle.

The ezLCD-301, features a new 2.6 inch diagonal color TFT LCD, providing 400 x 240 pixel resolution,

65,536 colors, 180 Nit brightness, LED back light, and an integrated four wire resistive touch screen. Its intelligent control module is highlighted by a 16-bit microcontroller, 4 Mbytes of Flash memory, USB 2.0, and RS232/TTL interfaces. The ezLCD-301 operates at a +3.3V supply voltage, draws less than 100 ma, and offers a 0 to 70°C operating temperature range. It is RoHS compliant and employs a mechanical outline of 2.69 x 1.61 inches, addressing 1U high (1.75 inch) product applications. Its low cost makes it a viable alternative to character modules, vacuum florescent displays, STN passive matrix displays, or more complex graphic LCD products.

The ezLCD-301-QK (Quick Kit) has also been introduced and provides a comprehensive, easy-to-use development platform for those interested in designing the ezLCD-301 into an existing or new product application.

The Quick Kit includes the ezLCD-301 module and a USB interface cable.

For more information, contact:

EarthLCD

3184-J Airway Avenue

Costa Mesa, CA 92626

Tel: 949-248-2333

Web: www.earthlcd.com

5 MHz FUNCTION GENERATOR WITH FREQUENCY COUNTER

Global Specialties, has re-introduced the new 5 MHz



function generator. The model 4005 has a number of features and functions not offered by other similar 5 MHz function generators on the market today. The 4005 is designed to be very vestal and can be used as a function generator, sweep generator, pulse generator, and a frequency counter. Cost is \$320.

VCF (voltage controlled frequency) produces precision sine, square, and triangle waves over 0.05 Hz to 5 MHz for sub-audible, audio, ultrasonic, and RF applications. A continuously variable DC offset allows the output to be injected directly into circuits at the correct bias level.

Variable symmetry of the output waveforms converts the model 4005 into a pulse generator capable of generating rectangular waves or pulses, ramp or saw tooth waves, and skewed sine waves of variable duty cycle. The sweep generator offers a linear sweep with a variable sweep rate and sweep width up to a 100:1 frequency change. The frequency response of any active or passive device up to 5 MHz can then be determined. The 4005 can be used in applications in both analog and digital electronics such as engineering, manufacturing, servicing, education, and hobbyist.

For more information, contact:

Global Specialties, LLC

Tel: 800-572-1028

Web: www.globalspecialties.com

SYNAPSE AND BRUTUSBOT KITS

Familiar with XBee? Of course! How about Synapse — not so much? The geeks at Solarbotics have been playing with the new Synapse 802.15.4 modules and feel they're more handy than the venerable XBee. Since Synapse modules offer more I/O, embedded microcontroller Python, A2D converters, and I²C, they offer a great way to upgrade wireless projects, especially with communication ranges up to 1,000 ft indoors and three miles outdoors (line-of-sight). To easily harness the new features offered by the Synapse RF100, Solarbotics is now offering two interfacing kits.

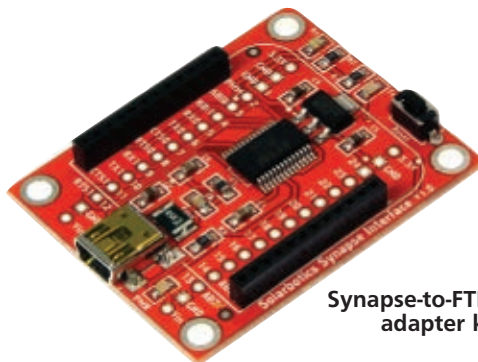
The Synapse-to-FTDI adapter kit interfaces the Synapse module to a PC with an FTDI USB converter, breaks the pins spacing out to 0.1", and generates the 3.3V power necessary to drive the module. Price is \$22.95 USD.

The Synapse-to-FTDI kit features:

- Fuse-protected USB-TTL interface (FT232RL chip).
- 3.3V 1A onboard voltage regulator.
- Tx/Rx/Power LEDs.
- Breadboard-compatible breakout headers.
- Reset switch (handy when erasing SNAPpyscripts or upgrading firmware).
- #4-40 mounting holes.

The Synapse-to-XBee Adapter Kit converts a Synapse module to a drop-in replacement for XBee RF nodes. Since the Synapse has extra I/O the XBee doesn't (and with embedded python), the adapter breaks out these points to LEDs and header pins for increased hacking power. Users can convert Arduino XBee projects to Synapse with this converter. Price is \$7.50 USD.

Solarbotics also introduces a new, more useful platform based on the Tamiya Bulldozer technology called



Synapse-to-FTDI adapter kit



Synapse-to-XBee adapter kit

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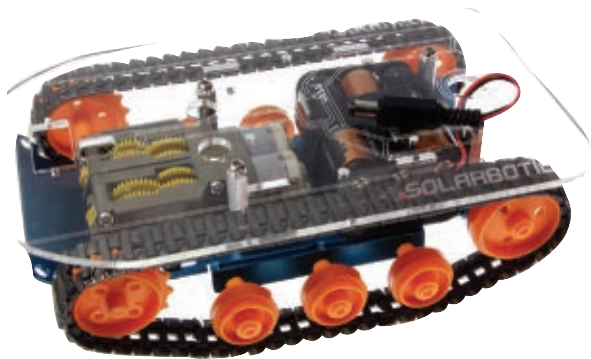
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the BrutusBot Tank Platform.

The BrutusBot features the Tamiya Gearbox and Tread set, anodized aluminum frame, and Arduino-compatible acrylic top-plate. Being just a motorized base, users can add any controller platform desired, from something as simple as an analog modified "Herbie" brain to as complex as a wireless Synapse networking module. Price is \$52 and features include:

- Rugged anodized aluminum chassis with skid plate.
- Grippy Tamiya rubber treads for excellent traction.

- Tamiya twin motor gearbox configurable for high speed (indoor/smooth environment) or high torque (outdoor/rough environments).
- Acrylic top-plate with cutouts for pass-through wiring ports and mounting a sensor-sweeping servo.
- Interfaces with Solarbotics S.A.F.E. enclosures to protect electronics in off-workbench environments.
- Six-cell 'AA' battery pack for excellent motor power and lifetime.

For more information, contact:
Solarbotics, Ltd.
 3740D 11A Street NE Suite #101
 Calgary, AB T2E 6M6 Canada
 Tel: 866-276-2687
 Web: www.solarbotics.com

UPGRADED EASYPIC v7

mikroElektronika announces the successor to their major development board for PIC microcontrollers: the EasyPIC v7.

For the first time in EasyPIC's almost 10 year history, EasyPIC v7 has grouped PORT headers, LEDs, and buttons into input-output groups, thus making them easier to use. The boards are equipped with tri-state DIP switches, so placing pull-up or pull-down jumpers to desired pins is now just a matter of pushing the switch.

Connectivity is the main focus of EasyPIC v7 which provides three separate PORT headers in the input-output groups, and another one on the opposite side of the board. This way, users can access those pins from any side.

The board has a dual power supply, supporting both 3.3V and 5V microcontrollers. Another feature of the board is its powerful on-board mikroProg programmer and In-Circuit

debugger, capable of programming over 250 PIC microcontrollers. Debugging is supported with all mikroElektronika PIC compilers (mikroC, mikroBasic, and mikroPascal).

The board has three displays: GLCD 128x64, LCD 2x16 character, and four-digit seven-segment displays.

EasyPIC v7 is the first board that supports the mikroBUS pinout standard. It now has new modules which include: serial EEPROM, piezo buzzer, and support for both DS1820 and LM35 temperature sensors.

For more information, contact:
mikroElektronika
 Web: www.mikroe.com

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 Rockledge, FL 32955-4200
 Tel: 800-645-5828
 Web: www.RENCOUSA.com

CEREBOT MC7 DEVELOPMENT KIT

Microchip Technology Inc., announces the availability of a Microchip dsPIC33 Digital Signal Controller (DSC)-based development kit. The DigilentCerebot™ MC7 development kit addresses the growing interest in embedded motor control from the academic and hobbyist markets, and is ideal for learning about microcontrollers and solving real problems. The kit includes a demonstration board that provides four half-bridge circuits, eight RC servo

Continued on Page 75

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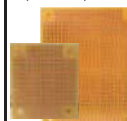
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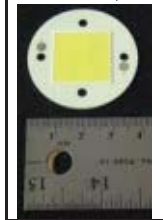
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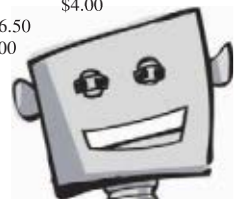
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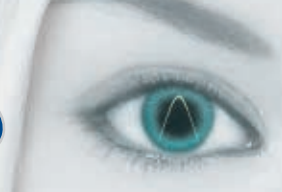
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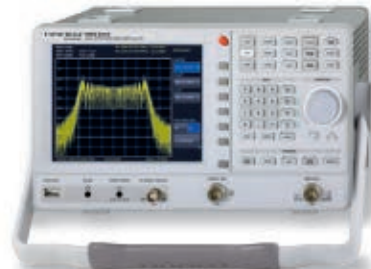
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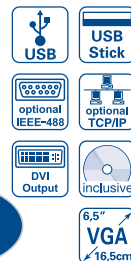
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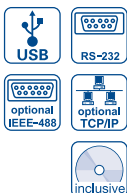
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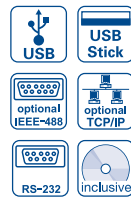


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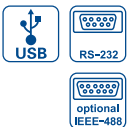


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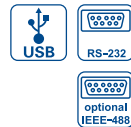
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A while back, I had purchased some electroluminescent (EL) wire from LiveWire (www.elbestbuy.com) and used it to decorate a shirt and a hat. The simple “on” or variable-speed flashing controller quickly grew boring. The sequencers had up to five colors of wire, but didn’t allow me to customize the patterns. I wanted more control and creativity, as any self-respecting hobbyist does.



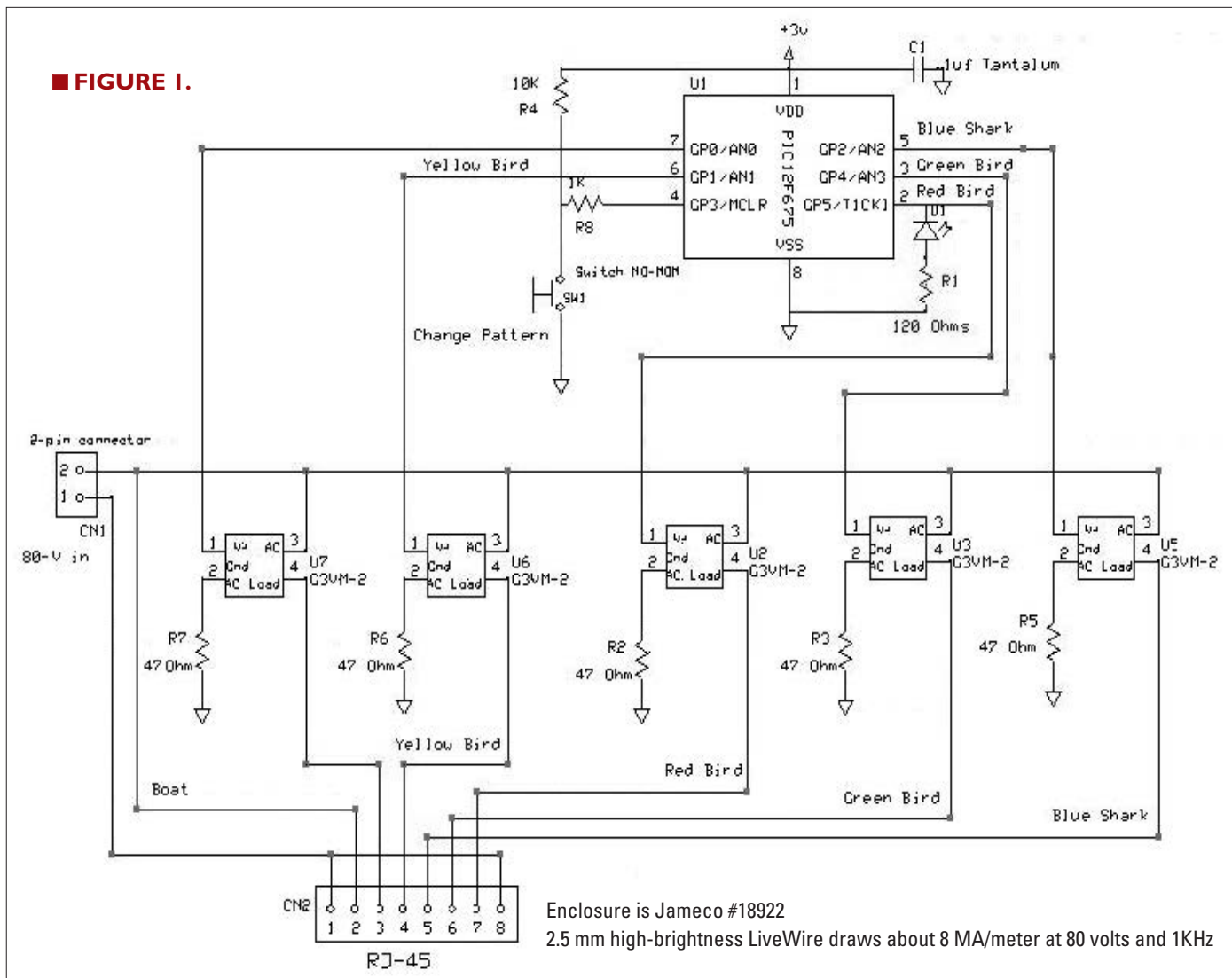
Putting a voltmeter on the inverter output, I found that it used 80 volts AC, driven at 1,600 Hz. I quickly figured out that it was going to take something more than a simple transistor driver to turn it on and off. I tried a couple of miniature relays with limited success, but they were just too bulky and power-hungry for wearable electronics. I finally found the G3 series of opto-isolated switches from Omron. These seemed to be the perfect answer. Feed them a simple three volt DC signal and they can switch up to 120 mA of 350 volts AC. Since EL wire draws under 8 mA per meter, each switch could drive 15 meters. No moving parts, either. I breadboarded a simple circuit with a G3VM-2 and found that they would easily make the EL wire turn on and off.

I had several goals in mind. I wanted to create a shirt with custom blinking patterns. I wanted the shirt to be at least hand-washable, so the electronics had to be removable. I wanted the controller to be compact, so I wasn’t dragging around a big box under my shirt. I didn’t want to electrocute myself. I also had to work within my own limited electronic knowledge.

I didn’t know enough about generating fairly high voltage AC from a battery-powered source to create my own driver. So, I decided to use the simple nine volt battery powered inverter from Live Wire and just insert my electronics between it and the EL wire.

I’ve used PIC processors before, so I thought this would be a great way to expand my knowledge. They

■ FIGURE 1.



offer a huge range of devices, the programming tools are cheap, and they seem well-suited to this task. Going back to my prototype board, I programmed a PIC12F675 to switch one of the pins on and off, fed the signal to the G3VM-2, and the EL wire blinked at my command!

Now, I had to design the controller. The shirt I had used with the simple inverter was an Eric Clapton concert T-shirt from many years ago (see **Photo 1**). Even when it was just a simple blinking guitar outline, it was popular at concerts. What could I do to improve it?

There was just enough room on the neck of the guitar to allow four wires across. The body of the guitar was another circuit, for a total of five circuits. The PIC12F675 has six I/O pins. If I reserved one for a switch to change the pattern, I'd have five output pins. That left just connecting the controller to the shirt. Looking around my parts bins, I spotted a spare Ethernet cable. Hmmm, eight wires. I checked the specs for the connectors, and they are rated for 120 volts AC at 1.5 amps. Five control lines, two grounds, and a spare. Perfect!

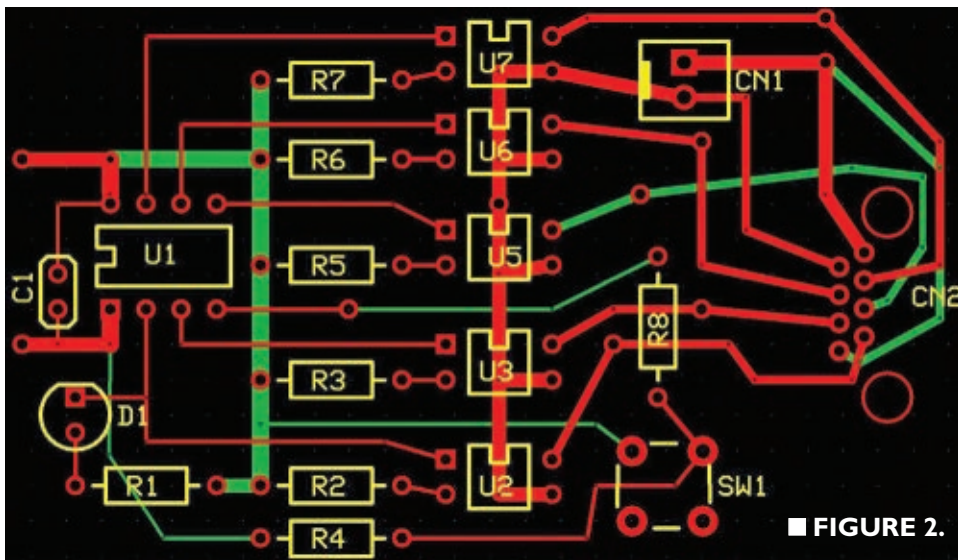
I now had all of my major components selected, so I

started on the schematic (see **Figure 1**). I used ExpressSCH from ExpressPCB (www.expressPCB.com). I assigned each pin on the connector to a circuit. I assigned the spare pin to an “always on” circuit. Each of the controllable circuits led back to a G3 switch (U2-U7; note that I numbered them to match the pin they are attached to), then to the PIC pin. The pattern-changing switch is connected to pin 4 through a 1K ohm resistor. The pin is pulled high through R9 (10K) until you press the switch.

Each G3 switch has a current-limiting resistor (R3-R7) to ground. They are also numbered to match the pin they are connected to. The G3 datasheet shows a typical current draw of 50 mA. Since I'm driving the PIC with three volts, the maximum I can expect on a “high” pin is about 2.7 volts. Plugging this into Ohm's law gives $2.7V / 0.05 A = 54 \text{ ohms}$. A 1/8 watt 47-ohm resistor will do the job nicely.

Printed Circuit Board

I designed the printed circuit board (PCB) to fit into a



■ FIGURE 2.

There is a small switch glued to a 1/4" hole drilled in the cover which allows you to turn the controller on and off. Measured power draw with all circuits on is about 33 mA, so two AAA batteries rated at 1,125 mAh should last over 30 hours.

Start by soldering the shortest components in place – the resistors. Next, install the taller ones: the processor socket, the LED, and the G3 switches. I soldered the bypass cap (C1) to the bottom of the board to keep it out of the way when I was pulling and re-installing the processor during software development. After

Jameco 18922 enclosure. It's 3.1" x 2" x .9" (inside), so I made the board 2.75" x 1.6" (see **Figure 2**). I ordered four of them from **Expresspcb.com** for about \$80. Note that you will have to cut off the corners of the board in order to clear the screw mounting bosses in each corner of the enclosure.

From left to right, the PIC (U1) is at the end, the current-limiting resistors come next (R2-7), then the G3 switches (U2-7), the selection switch (SW1) and high voltage input connector (CN1), and finally the RJ-45 jack (CN2). There is an activity LED (D1) and current-limiting resistor (R1) in the lower left corner of the board, connected to pin 2. This helps you determine if the board is functioning.

Assembly

Assembly is very easy; all of the components are through-hole. Three volt power comes in the left side of the board from a 2xAAA battery holder attached to the inside of the enclosure cover with double-stick foam tape.

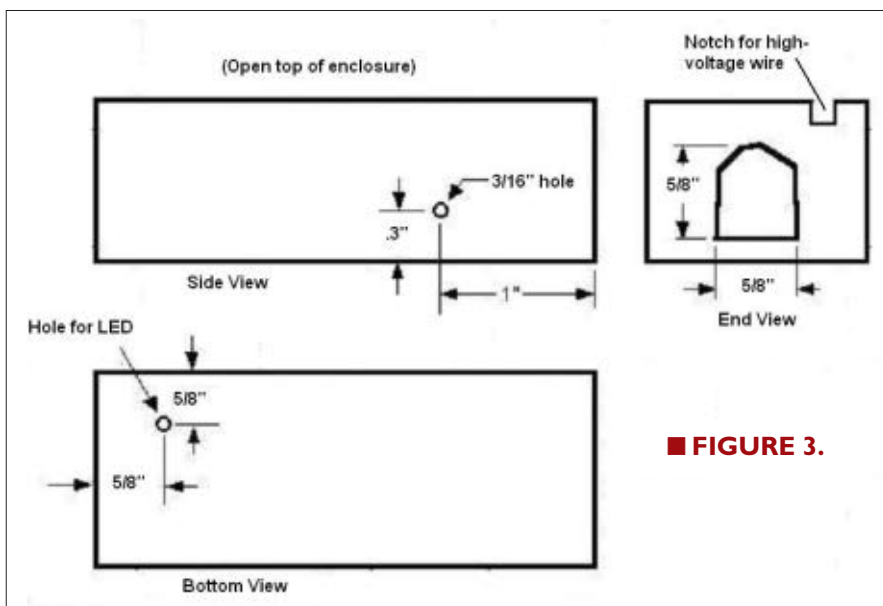
those components, install the pushbutton switch and the high voltage input plug. Notice I used just a simple two-pin plug. I soldered a two-pin socket I had lying around to the high voltage converter. This allows me to easily move it to another controller.

You may want to just directly solder the driver wire to the board. Even better, if you can find a source for the slick two-pin locking connectors on the inverters, you could have them plug directly into your board. (If you find them, please email me with the source and part number!) In any case, tie a knot in the wire as a stress relief and notch the enclosure so that you can feed the wire through before you attach the lid (see **Figure 3**).

The last component is the RJ-45 jack. Finally, connect the wires from the battery holder/switch. It should look like **Photo 2**. Notice that I put the activity LED on the top of the board. I've found that I tend to leave the controller on after using it, so I recommend that you install the LED on the bottom of the PCB and drill a hole in the bottom of the enclosure large enough for it to stick through. This gives you a visual indicator that the controller is on, without having to open the enclosure.

Now, program a PIC12F675 with the program available at the article link. I used a PICKit2, but there are many other options available. Do a web search for PIC programmers; you'll find several. After programming, plug it into the socket on the board. Install the batteries and turn it on. The activity LED should light. If it doesn't, check your battery connections and make sure that the PIC is oriented correctly. Press the pattern select button once or twice; the LED should start blinking.

Now, you need to prepare the enclosure. Drill a 3/16" hole in the side of the case to accommodate the pushbutton switch. Note the dimensions and location of the hole in **Figure 3**. You may want to make it a little oversized to



■ FIGURE 3.

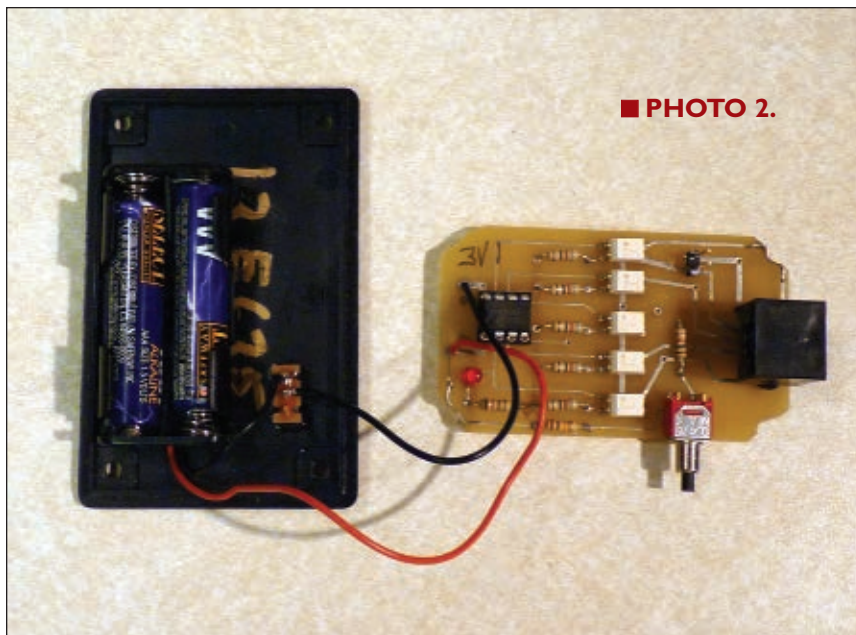
make it easier to insert and remove the PCB. On the end of the enclosure, cut a hole for the RJ-45 plug to go through. I used a Dremel tool to make this opening. If you decide to install the LED on the bottom of the board, drill a hole to accommodate it. Please verify all dimensions before you drill!

The Shirt Design

This is actually the more difficult part of the design. You need to find a shirt with a simple, bold design that you can add light to. I started with the guitar T-shirt, but I've also used parrot T-shirts from Margaritaville.com (see **Photo 3**). The schematic is labeled for this shirt. There is yellow wire on the yellow bird, red wire on the red bird, and green wire on the green bird. I used blue wire for the two shark fins.

The blue wire is also connected to a shark fin on the front of the shirt (the birds are on the back). This helps me see if the shirt is working, since I can't see the back very well. The always-on circuit is connected to white wire on the boat. The same circuit board and software is used for both shirts.

I used neon signs for inspiration; they have the same design limitations as EL wire. They have to be continuous strings and they can't be bent too sharply. You will want to make as few splices in the EL wire as you can. Remember that you can link together different colors into the same circuit, either by connecting them to the same wire on the Ethernet cable or by daisy-chaining to the end of another EL wire. You will need to sew a buttonhole in the shirt at each point the EL wire has to go through so that the shirt



won't fray. You will also want to cover the wire with shrink tubing anywhere it runs behind the shirt or it will show through when lit.

Figure out what sections should blink and in what patterns. Make careful notes about which processor pin you need to connect to what section of wire. Mark all of the EL wires with a piece of tape that shows which Ethernet wire it should connect to (blue, blue/white, etc.). This could save you many hours of debugging.

The EL Wire

Once you have firmed up your design, order enough EL wire. I usually buy 10 ft lengths of each color I want, along with a high powered inverter. You can also get the



■ PHOTO 3A.



■ PHOTO 3B.

Ethernet Pin #	Wire Color	PIC Pin	Bird Shirt	Guitar
1	Orange/White	Ground	Ground	Ground
2	Orange	—	Boat	Body of Guitar
3	Green/White	7	—	—
4	Blue	6	Yellow Bird	String #1
5	Blue/White	5	Blue Shark	String #2
6	Green	3	Green Bird	String #3
7	Brown/White	2	Red Bird	String #4
8	Brown	Ground	Ground	Ground

Table 1.

five-color CK-3 kit if you just need short pieces of several colors. For some designs, you may even be able to just lift the entire pre-made wire assembly and use it directly. If that's not practical, you will have to make your own wiring harness. The chart in **Table 1** will help you keep track of each circuit.

The extremely fine wires inside the plastic insulation can be difficult to work with. I found a pair of high powered reading glasses helped me locate them. There are a lot of tips on the EL Wire website. Click on the Site Map link and look under the soldering tips. Make your connections sturdy; you may be crowd surfing with this shirt on! Use generous lengths of shrink tubing on all of your connections. I used 22-gauge speaker wire to connect the EL wire to the Ethernet cord.

First, separate the speaker wire for at least one inch. Cut one wire about 1/4" shorter than the other; strip them both for 1/4". Next, strip about 3/8" of the colored jacket off the outside of the EL wire. Now, find the two very fine wires that spiral around the core inside the second clear layer. *Very carefully* strip off the second layer of insulation. Do not cut the wires! Fold them back out of the way. Scrape off 1/4" of the white layer covering the wire core. Put a piece of shrink tubing over the *shorter* speaker wire, and then solder that wire to the core of the EL wire. Once

it's solidly connected, pull the shrink tubing over the connection up to the two fine wires and shrink it into place. I used 3/32" shrink tubing for all of my connections, but you might want to get some 1/8" to make the outer ones slide over the inner ones easier. Solder the two fine wires to the longer speaker wire. Check that the wire lights when you apply power. After you confirm that the connection is good, put some shrink tubing over the entire connection and shrink it into place.

After each EL wire had a lead wire and was attached to the shirt, I routed them all down to the bottom edge of the shirt and connected them to the Ethernet cable. Sew them all solidly in place. Make the Ethernet cable long enough to reach the pocket where you intend to keep the electronics. Leave some slack.

Once everything is connected, plug in the controller and turn on the EL inverter. Your always-on circuits should light up. Next, power up your controller and press the pattern switch once or twice. Your EL wire should start blinking. Once you are sure everything works, wrap all of the wires together with larger diameter shrink tubing.

Sewing

You may want to take your shirt to a local alterations shop for the button holes. It's not easy to sew them into T-shirts. Don't even consider doing them yourself without a sewing machine that does automatic buttonholes. If you do them yourself, you may want to get some self-adhesive liner material (called interfacing) at a fabric store. I've had mixed success with it. Sacrifice an old T-shirt to the cause and practice both with and without the interfacing.

Carefully mark where you need the holes to be with a light pencil mark or a pin. Allow the automatic buttonholer to do its job. Note which way the sewing machine makes the buttonhole outline — probably AWAY from you. Now, apply a generous-size patch of the interfacing behind the shirt and try again. Select the method that works best on your fabric. You only need

about a 4 mm hole for a single wire; a 6 or 7 mm hole will accommodate two wires. Once you are good at buttonholes, go ahead and sew them in your shirt. Take a good pair of scissors or a seam ripper and carefully open up the middle of each one.

Now, thread your first piece of EL wire through the buttonhole. Lay it out on the shirt

PARTS LIST

QTY	DESCRIPTION	ID	SOURCE AND PART #
5	47 ohm, 1/8 watt resistor	R2-4, R5-7	Digi-Key CF18JT47R0TR-ND
1	1K ohm, 1/8 watt resistor	R8	Digi-Key RNF18FTD1K00CT-ND
1	10K ohm, 1/8 watt resistor	R4	Digi-Key RNF18FTD10K0CT-ND
1	120 ohm, 1/8 watt resistor	R1	Digi-Key CF18JT120RCT-ND
1	Pushbutton switch, NO	SW1	Jameco 71643-2
1	.1 µF capacitor	C1	Jameco 15270
1	LED, any color	D1	
1	Eight-pin DIP socket		Digi-Key ED2202-ND
1	PIC12F675 processor	U1	Digi-Key PIC12F675-I/P-ND / Jameco 223781
1	RJ-45 socket	CN2	Digi-Key WM5432-ND
5	G3VM-2L opto-isolated relay	U2-3, U4-7	Digi-Key Z2710-ND (note new "L" version)
1	Enclosure		Jameco 18922
1	Slide power switch		Jameco 109171-3
1	Two "AAA" battery holder		Jameco 616283-3
10 ft	3/32" shrink tubing		Jameco 644834
1 roll	24-gauge speaker wire		Jameco 100280
1	Ethernet patch cord		Jameco 2115602
1	Two-pin .1" C-C header	CN1	Jameco 108338
1	Two-pin socket		Taken from old computer case

exactly where it needs to go and tape or pin it down. Sew the wire in place firmly by hand; a sewing machine can't do this job. Use heavy thread or a double strand of lighter thread. Be careful to not puncture the wire! Repeat for each strand of wire.

This is where it pays to know someone who can sew. Having an experienced hand help here is worth more than you can imagine. Use thread the same color as the shirt so that it blends in. I found that I needed a loop over the wire about every 1/2" in order to hold it securely in place. Put the loops closer around tight curves. The specs say you shouldn't bend the EL wire any tighter than the radius of a dime, but I've made tighter corners and haven't had any problems (yet). Tie every stitch firmly with a square knot. Double-knot them at high stress points (like where they go through the buttonholes). Don't forget to put shrink tubing over EL wires routed behind the shirt so that they don't show through.

The Software

If you've tested everything up to this point, all you have to do is turn it on; everything should work. However, you may want a different pattern than I used. That's the whole point here. Be creative! The software is labeled for the three-bird T-shirt I made, but it will work just as well for a guitar design. Use the three birds and the shark for the guitar strings. I used the always-on circuit for the body of the guitar, but you could use pin 7 to blink it, too.

The code is all written in PIC assembly. It's broken up into several subroutines that are called from the main loop. There's a delay loop used for blinking that also checks the pattern selection switch. The processor runs off the 4 MHz internal clock; if you change this, you will have to adjust the delay code.

The switch code rotates an eight-bit variable called "Direction." Whatever bit is on selects that pattern in the main loop. There are subroutines to blink each of the pins. Those are, in turn, called from subroutines that combine them into patterns.

Note that the one to blink pin 7 is not called since neither of these

designs use it. BirdLoop2, for instance, blinks the guitar strings (or the three birds) in one direction or the other, depending on the value in Direction. The StayOn routine turns on all of the strings and waits for you to press the selection button (this is the default pattern when you turn it on). The BlinkOne routine will blink one of the strings, again based on the value in Direction.

I've just scratched the surface of what can be done with my code. You should customize it to go with the shirt design you come up with. There's plenty of code space available, so if you feel like programming the cords for "Stairway to Heaven," go for it. Have fun! **NV**

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BUILD THE RTC OSD FOR

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1/86s 7.8mm

By Kelly Lewis

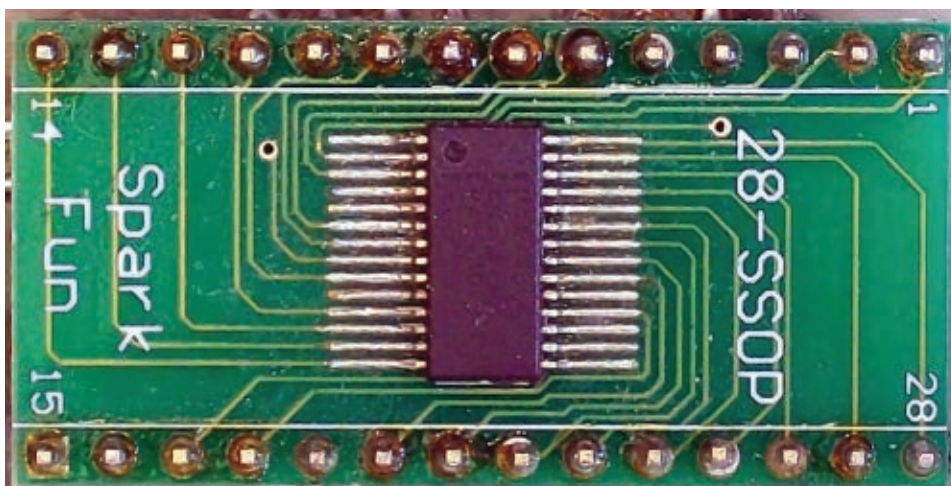
A real time clock-based on-screen display for closed-circuit television camera recording.

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

Closed circuit television (CCTV) camera systems have been in use for years in commercial areas such as banks and supermarkets, but with camera prices being more affordable, CCTV is now used more and more to protect homes and private property. Unfortunately, recording systems such as DVRs and time-lapse VCRs can be expensive, so an old VCR is sometimes used instead. However, without time stamps on the recordings, it can be difficult to determine when an event occurred.

I installed two affordable CCTV cameras with infrared for night vision around our yard to deter any potential troublemakers. An old Sharp VCR was put into service as a time-lapse VCR using a circuit that I built to switch between the two cameras and control the VCR

using IR signals, but I had no way of knowing when events had happened because the VCR does not write the date/time on the video recording. So, I built the RTC OSD (real time clock on-screen display) to provide an accurate time-stamp for the recordings.



HOW THE CIRCUIT WORKS

The circuit is made quite simple through the use of function-specific chips and a Microchip PIC to tie them together. Video display can be very tricky to get right, but the MAX7456 makes displaying

■ **FIGURE 1.** MAX7456 mounted on a 28-pin SSOP to DIP adapter.

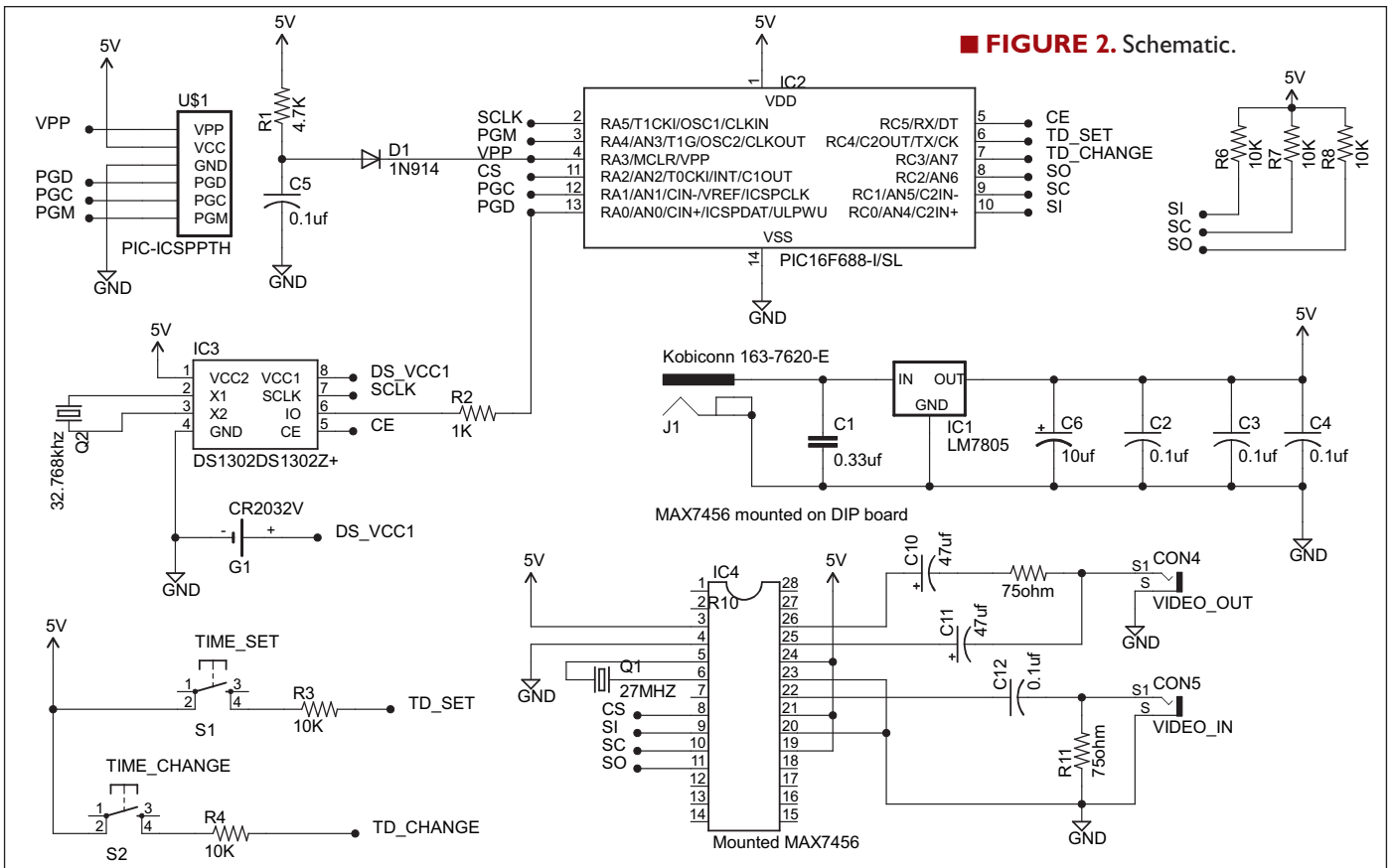


FIGURE 2. Schematic.

information easy. Additionally, the DS1302 timekeeping chip makes keeping time easy. A PIC16F688 ties everything together into a functional circuit. By inserting the RTC OSD between the output of a CCTV camera and the input of a VCR, it is possible to have a date/time stamp written on all recordings.

THE REAL TIME CLOCK

Initially, I tried using a PIC12F683 with the MAX7456 and no timekeeping chip. Certainly one of the timers in the PIC would suffice, or so I thought. Basing the timekeeping functions on an internal timer was not optimal as program complexity increased. Trying to work around the limitations of not interrupting communications in progress to the MAX7456 while keeping concise time was impractical.

Next, using the Microchip Application Maestro to include an RTC seemed like a good idea, and it actually worked quite well. I'd recommend giving it a try if you have a project that has no other timing constraints as the software RTC triggers interrupts causing slight variations to other time-critical functions that require accommodation. I briefly considered using a PIC24F* series chip but decided against it as I already had a PIC16F688, and it would do just fine with a little help. Since a DS1203 is relatively cheap and it simplifies battery backup, it just seemed easier than

fussing with software.

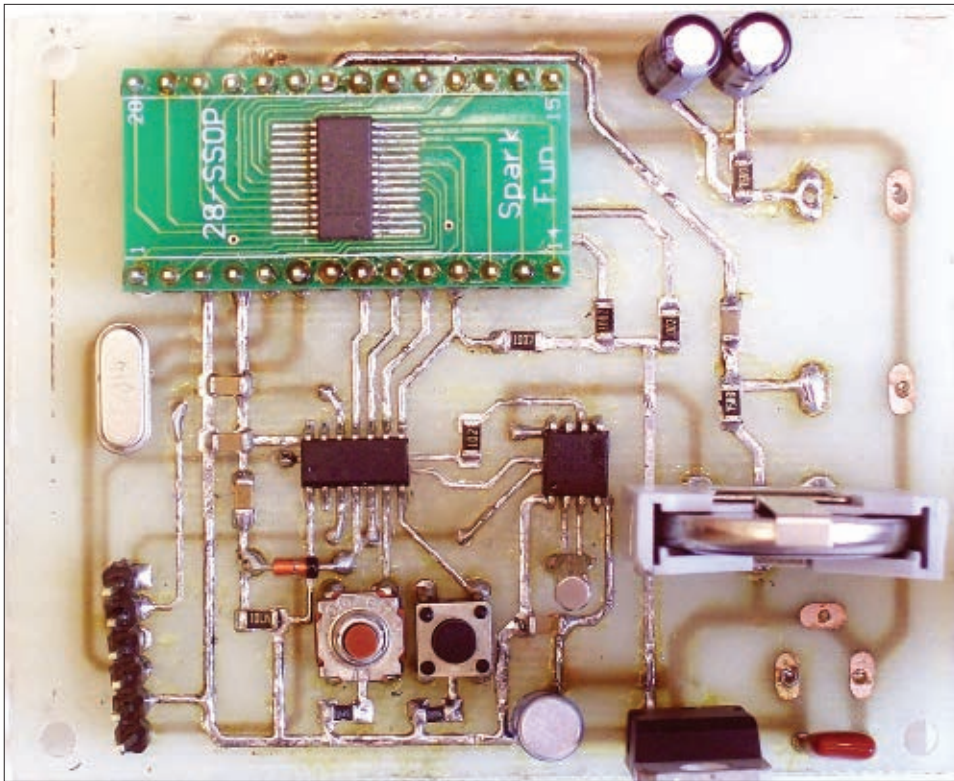
The DS1302 chip simplifies timekeeping since you just set the time and away it goes. Anytime you need to know the time, you just request it through the simple serial interface. There's no need to calculate anything as it is all done by the DS1302 with no need for interrupts. Not that interrupts are anything to fear, but for a hobbyist, the simpler, the easier, the quicker, the better.

ON-SCREEN DISPLAY

On-screen display can be challenging and in this case, it was made reasonably easy by using the MAX7456 for displaying the date and time. There are circuits available online for displaying on-screen data, plus other OSD chips are available, but I found the MAX7456 chip to be the easiest of the available options for the price. The connections are simple: video in and video out with a small number of supporting components. Four connections to the PIC16F688 are all that is needed for the serial interface (SPI).

The MAX7456 is a 28-pin TSSOP package, thus the pins are very close. I created the board for this project using the laser toner transfer method, which worked quite well. I was able to create the pad layout for the 28-pin TSSOP, lay the chip on it, and even solder it, but not without trepidation.

After spending a great deal of time using solder wick



■ **FIGURE 3.** Completed circuit board in use. The board was etched to accommodate RCA jacks, but I ended up using direct wiring instead.

to clean up the solder mess, and after examining the chip pins with a magnifying glass over and over, the chip failed when I powered up the circuit. I had overlooked the exposed pad beneath the chip — or it may have failed because of a hairline connection or failure between pins that was nearly invisible. Checking connections with an ohmmeter and a magnifying glass revealed no problems. There was no way of truly knowing if every connection was dependable without a microscope, which I do not possess.

To prevent a repeat of my last soldering mistake, I ordered a “SSOP to DIP Adapter 28-Pin” (BOB-00500) from SparkFun and rerouted traces on the board for a 28-pin DIP instead of a 28-pin SSOP. I do not work for SparkFun, but I can certainly recommend their breakout boards as being easy to use and reliable. Their 28-pin SSOP adapter has more accurate spacing than possible using the toner transfer method and it does not have traces beneath the SSOP chip. The adapter solved the exposed pad problem and made soldering the MAX7456 much easier.

CONSTRUCTION

I chose to use SMD parts whenever possible because I’ve actually found it easier to use them than through-hole parts. That may come as a shock to some hobbyists, but when it comes down to etching your own board, the fewer holes you need to drill, the better. Using the most narrow, flat, soldering tip possible with small diameter solder is a necessity for hand-soldering SMD parts — especially SSOP packages. Round

soldering tips tend not to hold a tiny amount of solder on the tip as well as a screwdriver or flattened tip does. However, I’ve also learned to stick with 1206 packages and SOIC packages whenever possible. SSOP can be done by hand, but it is challenging unless you have the hands and eyes of a surgeon.

For vias, I’ve always just used a piece of wire or component lead and soldered the lead into the via. However, what happens when you need to mount a radial package electrolytic capacitor with traces connecting to the through-hole leads on the top and bottom of the board and you don’t have a way to do plated

vias? There’s no way to solder underneath a radial capacitor without mounting the capacitor in an awkward looking way. In those cases, I usually route the traces in such a way as to avoid the problem, but that isn’t always practical and in some cases it can contribute to making the etched board bigger.

One solution that I came across on the Dallas Personal Robotics Group website was included in a video by Doug Paradis wherein he described a way to create a plated through via without using chemicals. He describes using copper foil — available from craft stores — to form a tiny tube of copper to fit into the hole on the board that needs to be through-plated. The copper tube works well but if the board hole is too tiny, then you just will not be able to form a small enough tube to fit into the hole. For more information on the method, visit <http://youtu.be/iU6LPvFEYeY>.

THE FIRMWARE

The PIC16F688 code was written in C using the free version of the Hi-Tech C compiler available from Microchip within MPLAB version 8.66. The code initializes I/O, initializes the RTC, initializes the OSD, checks for user input for changing the date/time, and outputs the date/time for recording or displaying on a CCTV monitor or television screen.

Although the sample code for the DS1302 was for an 8051 chip, it was in C and I was able to extract the sections of the code that I needed and port them over to the PIC16F688. The DS1302 has the ability to provide the date/time in AM/PM format or 24-hour format, so I

chose the 24-hour format as it was a little easier to use.

The DS1302 outputs data in binary coded decimal (BCD). The DS1302.c code translates the BCD data into character values the MAX7456 can use. For instance, if the DS1302 sends data stating the date is "04 29 2011," then the data sent to the MAX7456 to display this information would be "0x0A, 0x04, 0x47, 0x02, 0x09, 0x47, 0x02, 0x0A, 0x01, 0x01" where 0x47 is a "/" character. The output on-screen would be "04/29/2011."

Both the DS1302 and MAX7456 code use simple serial code, or what would be "ShiftIn" or "ShiftOut" in Basic. However, the DS1302 code uses quite a lot of bit shifting after receiving data simply because of the format that the data is in. On the other hand, the MAX7456 code is straightforward as data is either shifted in or out as listed in the shiftdata.c code. Oddly, neither code set needed delays as is sometimes needed when doing bit shifting.

The "ShiftIn" sections for each device were just different enough to prevent reuse. Besides, I had already created the shiftdata.c code for the MAX7456 based upon sample code on the Maxim website long before creating the DS1302 code, and found it much more effective to keep the code sections separated.

When the circuit is first started, naturally the

date/time will need to be adjusted. This is accomplished by using the two board-mounted pushbuttons in a fashion similar to a digital watch. When the "TimeSet" pushbutton is pressed, the code state changes from time display to time change. The first digit in the date/time will blink on the CCTV display while pressing the "Time Change" pushbutton increases the blinking number until it wraps around to zero. Wrapping around does not increment the adjacent digit.

Upon attaining the desired digit value, pressing the "Time Change" pushbutton will cause the next digit to the right to blink as it is ready to be changed. The blinking digit is changed using the "TimeSet" pushbutton after which the next digit blinks, and so on until all digits are changed as desired. The date/time will continue to change even if the RTC OSD is left in "TimeSet" mode. If "TimeSet" mode is not exited by setting the last digit in the date/time, then the digit being changed using the pushbuttons will continue to blink forever.

CONCLUSION

The RTC OSD provides an easy way to add a time stamp to a CCTV camera recording as programmed. Simply plug the CCTV camera or CCTV switcher into the video input of the RTC OSD, and plug the video

PARTS LIST

ITEM	QTY	DESCRIPTION	SUPP.	SUPP. PART#	MNF.	MNF. PART#
C1	1	0.33 µf 100V radial capacitor	Mouser	598-M30U334M1-F	Cornell-Dubilier	M30U334M1-F
C2-C5	4	0.1 µf 50V capacitor SMD 1206 package	Mouser	80-C1206C104M5R	Kemet	C1206C104M5RACTU
C6	1	10 µf 25V radial electrolytic capacitor	Mouser	598-SEK100M025ST	Cornell-Dubilier	SEK100M025ST
C10,C11 CON4,	2	47 µf 16V radial electrolytic capacitor	Mouser	598-SEK470M016ST	Cornell-Dubilier	SEK470M016ST
CON5	2	RCA connectors — panel mount	Mouser	502-BPJR04X	Switchcraft	BPJR04X
D1	1	1N914 diode	Mouser	512-1N914	Fairchild	1N914
G1	1	Battery holder for battery type CR2032V	Mouser	614-VBH2032-1	Renata	VBH2032-1
IC1	1	TO220 package five volt DC one amp low dropout regulator	Mouser	511-L4941BV	ST Micro	L4941BV
IC2	1	SOIC package PIC16F688	Mouser	579-PIC16F688-I/SL	Microchip	PIC16F688-I/SL
IC3	1	SOIC package DS1302 RTC timekeeping chip	Mouser	700-DS1302S	Maxim	DS1302S+
IC4a*	1	TSSOP28 package MAX7456 OSD chip	Mouser	700-MAX7456EU	Maxim	MAX7456EU+
IC4b*	1	SSOP to DIP adapter 28-pin	SparkFun	BOB-00500	Sparkfun	BOB-00500
J1	1	163-7620-E power jack	Mouser	163-7620-E	Kobiconn	163-7620-E
Q1	1	27 MHz crystal	Mouser	815-ABL-27-B2F	Abracon	ABL-27.000MHZ-B2F
Q2	1	32.768 kHz crystal	Mouser	815-AB38T-32.768KHZ	Abracon	AB38T-32.768KHZ
R1	1	4.7K SMD 1206 package	Mouser	652-CR1206FX-4701ELF	Bourns	CR1206FX-4701ELF
R2	1	1K SMD 1206 package	Mouser	652-CR1206-JW-102ELF	Bourns	CR1206-JW-102ELF
R3,R4,						
R6,R7,R8	5	10K SMD 1206 package	Mouser	652-CR1206FX-1002ELF	Bourns	CR1206FX-1002ELF
R10, R11	2	75 ohm SMD 1206 package	Mouser	652-CR1206FX-75R0ELF	Bourns	CR1206FX-75R0ELF
S1,S2	2	Mini pushbutton switch	SparkFun	COM-00097	Omron	B3F-1060
U\$1	1	2.54 mm breakaway vertical header	Mouser	517-929834-01-36-RK	3M	929834-01-36-RK

*Note: IC4a and IC4b are represented on the schematic as one unit being that the MAX7456 mounts to the SSOP to DIP adapter, thus creating one unit: IC4. Also, 28 of the breakaway pins of U\$1 are used for mounting the adapter.

output of the RTC OSD into a VCR or even a DVR for recording, then apply 7 to 9 VDC power.

Of course, there is opportunity for customization. The RTC code could be changed to output in AM/PM format and the MAX7456 could display it as such. The MAX7456 code could be changed to alter the appearance of the characters as custom characters are supported. Even multiple lines could be displayed, with one being the title of the camera area and the other being the date/time.

Bear in mind that the MAX7456 is designed for use with NTSC and PAL equipment. If you attempt to display a line at the bottom of the screen — row 16, for instance — and you are using an HDTV as a monitor, the line will display somewhere near the middle of the screen because the MAX7456 will not output past scanline 525 as a 1080p HDTV has 1080 scanlines.

When dealing with high frequency signals, it is often necessary to include a ground plane. The board that I created does not have a ground plane, and it was created using the toner transfer method rather than having it professionally etched. I found no need for the ground plane as long as I did not run wires underneath the board, in which case slight signal noise was noted. If you'd prefer to have the boards etched professionally, you might want to edit the Cadsoft Eagle PCB to eliminate the SSOP to DIP adapter.

If editing is done, be careful not to run any traces under the MAX7456 because of the exposed pad, unless you intend to connect the pad. Consider ordering solder masking and even tinning to make soldering the MAX7456 a little easier. All of these options can be quite expensive compared to a basic double-sided board order, hence I used the SSOP to DIP adapter and saved quite a bit of money in board etching costs. Although the dat sheet for the MAX7456 indicates that the exposed pad should be connected to a similarly sized pad on the component side of the PD board to aid in heat dissipation, I've had no problems with the chip for the last several months.

If this board was going to be made into a commercial product, then a ground plane would certainly be recommended. In fact, referring to the MAX7456EVKIT datasheet for a board layout example would be strongly recommended.

At last check, the MAX7456 was priced around \$20 at **Mouser.com** and the DS1302 was about \$4. This \$20 may seem expensive, but it is worth it for the amount of time that it saves and the simplicity of use. Also, the last time that I checked, Maxim has a special program providing free samples for potential customers that are in school and have an education based (.edu) email address. **NV**

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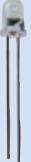
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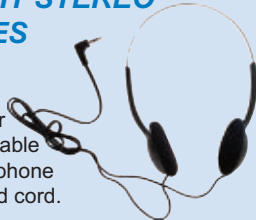


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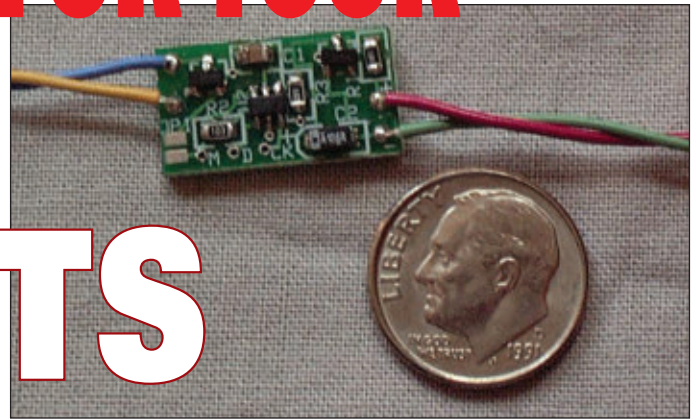


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PILL TIMERS — BIG MEDICINE FOR YOUR LITTLE PROJECTS



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I recently needed to update a design for a small five-second “power on” timer, and decided to use Microchip’s PIC10F2xx series microprocessors. In looking at the PIC10F200, I began to get carried away with the size. The surface-mounted version is a six-pin SOT-23 package outline which is smaller than some surface-mount transistors I have. That got me thinking about how else I could make the timer circuit smaller but more versatile than my older thru-hole design.

Taking pen in hand, I started writing down what I wanted in the design:

- Have the means for in-circuit programming.
- Work with voltages up to 24 volts.
- Use all surface-mount technology.
- Have a transistor for control of devices such as mechanical relays.
- Tolerate a 10 msec dropout.
- Selectable sense of output.
- Use internal timer instead of stacked delay loops.

I began to realize that this little circuit — with in-circuit programmability — could be used for a number of different yet similar functions such as flashers or pulse generators. With a minimum of external components, the device would be all in the software, which is the way microprocessor designs should be. The idea began to form of making a circuit so small and universal that it would be a component on its own, which could then be wired into a project the same as a resistor or capacitor. This could be something really useful for doing a lot of small, quick projects around the home and lab.

Having decided on the PIC10F200, I drew up my circuit schematic starting with the microprocessor. Since I have a bunch of surface-mount 2N2222 transistors, I decided on it for my load driver. The transistor can continuously carry a load of 600 mA — more than enough to drive a number of common relays. I chose a simple zener diode voltage regulator since it would be the cheapest, and voltage regulation wasn’t critical. With an operating voltage ranging from 2.0 to 5.5 volts, a zener regulator would allow the circuit to operate down to about two volts, while with a five volt regulator — such as a 78L05 (TO92 versions) — it would mandate a minimum operating voltage of about 7.5 volts.

Doing a quick layout of the circuit board, I soon had an elongated circuit board that was about the size of a large pill ... hence the name, pill timer. This was because the circuit has so few parts. Encouraged, I began working the circuit over to determine the values needed for the components; in particular, the zener voltage regulator. The five to 24 volt range is rather large, so I needed to determine a value for R1 (see **Figure 1**, schematic) which would give me that range.

Using Mathcad and my SPICE circuit simulator, I

started doing calculations of power dissipation for both R1 and D1. For a 4.7 volt zener and a minimum input voltage of five volts, R1 would have a value of just 10 ohms. The only trouble is – for the maximum input voltage of 24 volts – R1 would dissipate 38 watts while the zener diode had a load current of almost two amps. Obviously, more work was needed on the design. R1 would need to be a much larger value.

The maximum continuous current for the surface-mounted version of the 2N2222 is 600 milliamps, and for a DC beta of 150, the base current is four milliamps. So, working with this, I tried different values of R1 and input (battery) voltages while monitoring the current through the zener diode and output voltage. One big plus is the PIC10F200 operates from 5.5 volts down to 2.0 volts, so I didn't need good regulation; I just needed to limit the voltage to under 5.5 volts.

One thing quickly became apparent: I wasn't going to get my 24 maximum operating volts. It looked like 15 volts was going to be the best I could do, which is about the maximum encountered in electronic circuits. In automotive systems, the voltage will reach about 16.5 volts while the engine is running, so this could be a problem. So, if a pill timer is to be used in an automotive circuit, the value of R1 may need to be increased to give a greater voltage drop, thereby reducing the current through zener diode Z1.

SMD and In-Circuit Programming

The next objective of having In-Circuit Development (ICD) programming ability defeats the goal of using surface-mount devices because normally, ICD requires a header pin set to plug the programmer in. The traditional SIP headers I use for ICD would be bigger than the anticipated size of the pill timer's circuit board, so something better was needed. In addition, I also wanted to keep all the components mounted on one side of the board, so the circuit would lay flat on a surface.

What I needed was something like finger pads on the edge of the circuit board that would allow the pill timer to be plugged into a connector with finger

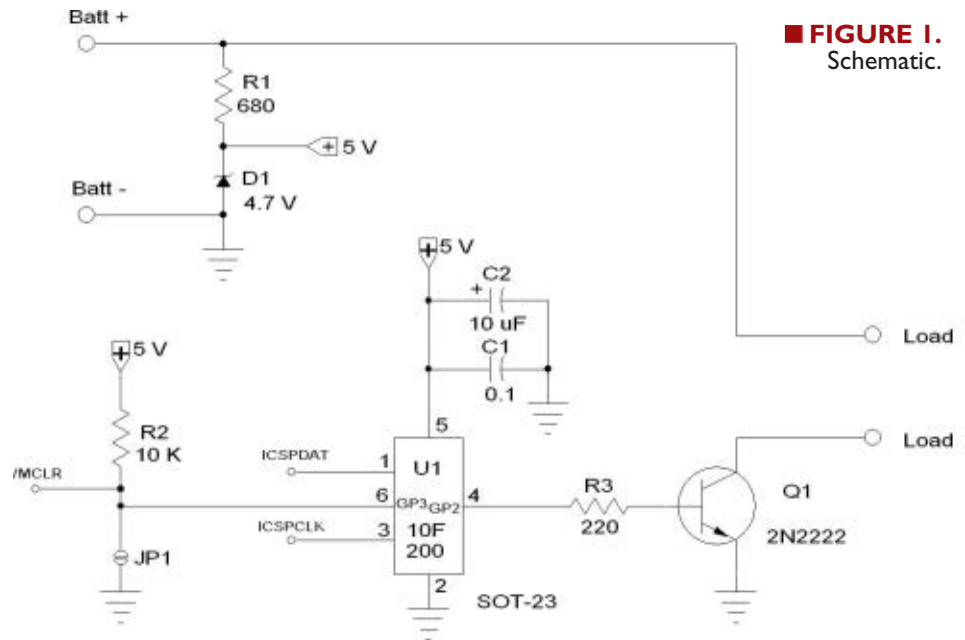


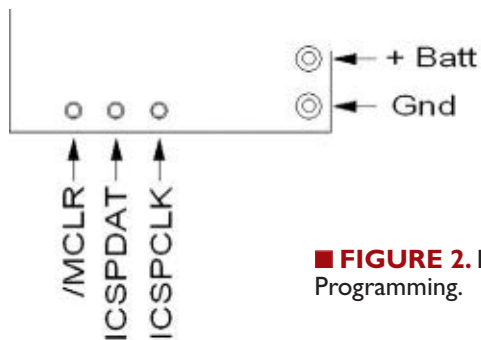
FIGURE 1. Schematic.

contacts. The trouble is there isn't any standard connector available that would fit the bill. I would need a custom-built device using several small precision made parts. Sounds like a lot of time and effort with the lathe and milling machine. This would be something difficult for most amateurs to reproduce. I thought about trying to use an RJ-9 jack with an insert that would force the circuit board up and make contact with the finger pads. That would make the circuit board layout larger, however, and I wanted to keep it as small as possible.

The most difficult part of doing a custom connector is ensuring all contacts make and hold electrical contact; the tolerances just become too tight. I then thought about implementing thru-hole vias used to route lands from one circuit board layer to another. The small hole would give an anchor to hold a pin in place when pressure is applied. If I took a common straight pin, bent the tip over 90 degrees, then fixed it in a spring lever so the spring pressure would hold the pin down in the hole, it would then be easy to reprogram the timer.

PARTS LIST

ITEM	QTY	DESCRIPTION	Digi-Key PART#
C1	1	0.1 µF capacitor, ceramic, 25V, 10% X&R SMD 0805	PCC1828CT
C2	1	10 µF capacitor, tantalum, 10V 20% SMD 1206	718-1118-1
D1	1	4.7 volt zener diode, SMD SOT-23	BZX84C4V7LT1GOSCT
Q1	1	2N2222A NPN transistor, SMD SOT-23	MMBT2222ALT1GOSCT
R1	1	680 ohm, 5%, 1/8 watt, SMD 0805	P680ACT
R2	1	10 Kohm, 5%, 1/8 watt, SMD 0805	P10KACT
R3	1	220 ohm, 5%, 1/8 watt, SMD 0805	P220ACT
U1	1	PIC10F200 microprocessor	PIC10F200T-I/OTCT

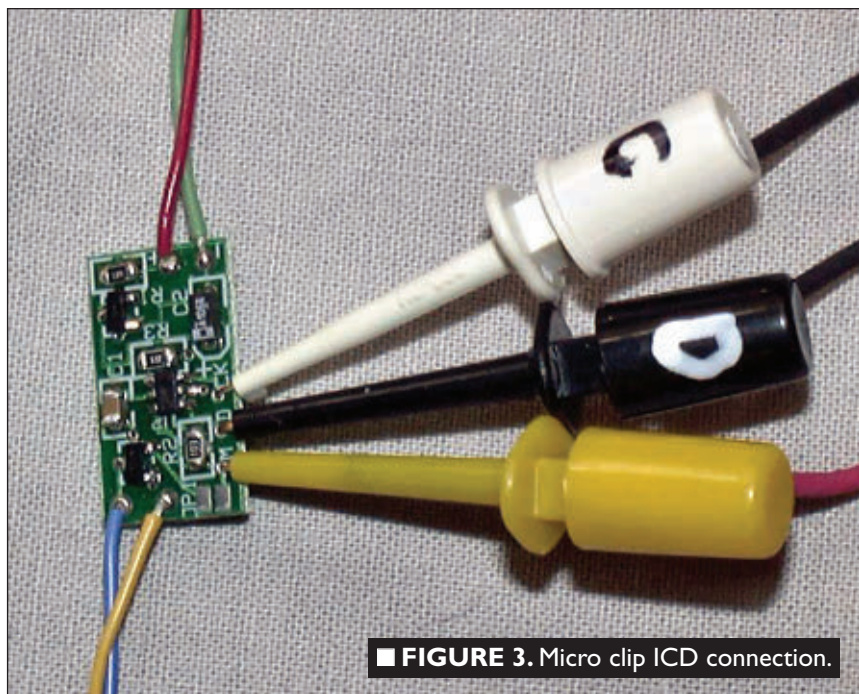


■ **FIGURE 2.** In-Circuit Programming.

Finally, it occurred to me that if the holes were large enough and were close enough to the edge, I could simply use micro grabbers and hook each wire onto the board. This would be much easier than building a spring loaded clip connector. As shown in **Figure 2**, the three signals used for Microchip’s ICD would be “thru holes” set on the edge of the circuit board, so the hook of a micro clip could be inserted in the hole and hold when released as shown in **Figure 3**. This would mean the hook would need to be straightened out — an easy job done with needle-nose pliers.

Some of the clips were just a shade too wide, but using a rotary power tool with a sanding cylinder, I sanded the clip end down and also made it more pointed so it was easier to insert the clip in the small hole. I then made an adapter for my Microchip PICkit 2® programmer (Digi-Key PG164120 @ \$34.99 each) that allowed me to easily connect the programmer to the pill timer. Also, clips for the power and ground allow the pill timer to be programmed without external power. The power (red clip) and ground (green clip) are connected to the power and ground inputs of the circuit board.

The adapter is simply a six-pin single inline (0.1 inch



■ **FIGURE 3.** Micro clip ICD connection.

spacing, 0.025 inch square post) that the PICkit 2 can plug into, and has short test leads connecting each pin to a micro grabber as shown in **Figure 4**. I used regular high flexible, small wire, test lead (Belden 8890, 0.088 inch diameter) which is kind of pricey, but you can also make all your own test leads. The small diameter of the test lead wire makes clipping several test leads to a circuit a lot easier. A different color micro grabber is used for each signal, with red and green used for power and ground. The /MCLR is yellow and the ICSPDAT is black; the ICSPCLK is white.

The data and clock are also marked with a letter using a small paint pen. Looking closely at the header, you can see the top end of the header pin strip is marked with white paint to indicate polarity when plugging into the PICkit 2 programmer; it should be opposite the white index mark on the programmer as shown in **Figure 5**. This shows the PICkit 2 programmer connected to the pill timer, ready to download the program into the PIC10F200. So, if you have a timer programmed for a 10 second delay and you find that 20 seconds would be better, the timer can be quickly reprogrammed with the new delay.

Note that the PIC10F200 is a Flash device, meaning new programs can be loaded as many times as you want; the program remains in the device when the power is turned off.

Selecting Sense of Output

I wanted to select if the output was high or low on power-up, and then after timeout, switch the sense of the output. This could be done in software, but that would mean another change in the program before assembling.

Plus if the sense wasn’t right, then reprogramming would be required to correct it. Since the /MCLR (bit 3 on G port) is read only and already has a pull-up resistor, I decided to do a hardware select using a solder short jumper. This way, just a quick touch of solder and hot iron will form a solder bridge across the pads, and just as quickly, a touch of the iron with solder wick will remove it.

With the pads open, the pull-up resistor R2 would give a high input level when bit 3 is read, while a solder short would give a low-level input. The program would check the input level and decide what to set the output level at on power-up. The one disadvantage is the solder short can’t be in place when the in-circuit programming is used. If you want to reprogram the device when the pads are shorted, you must first solder-wick the short to open the jumper, then the programmer will work correctly.

Since canned programs are being used

to program the time delay, I don't think this will be a problem, since there shouldn't be any debugging required. This will only be a concern if you decide to change the time value.

The Software

On my original timer, I used a canned subroutine called "stop watch" where I would load in a desired time delay in microseconds, milliseconds, and seconds expressed in tenths of a second, then called the subroutine. Using a series of timing delay loops and counters, the subroutine delays the amount of time desired, and when that time was up, returned to the main program. Although tight, the PIC10F200's ROM could accommodate this subroutine, but I got to looking at its timer **TRM0** function. The more I thought about it, the more elegant it looked to use the internal timer for the basic timing. After a quick test to use the **TRM0** as a pseudo oscillator, I was hooked! This would be the way to go.

The PIC10F200 has only one internal timer with no interrupt capability (refer to Microchip's datasheet). This means you must continually read and check the value of the counter register **TRM0**. To start the time, you set bit 5, **TOCS** (Timer0 Clock Source select bit) low to select the internal oscillator as the clock source, so each instruction is one microsecond. Next, set bit 3 **PSA** (Prescaler Assignment bit) low to select the prescaler for the timer. This will multiply the one microsecond clock by the prescaler value to increment the **TRM0** register. Finally, set bits 0-2 to high to select a prescaler of 256. Now, the timer register **TRM0** will increment every 256 microseconds. The following two lines of code (**Program Listing 1**) from `PT_5xsec.asm` accomplishes starting and configuring the timer, and is executed at the start of the program.

For doing a time increment, I wrote a subroutine called `Dly50ms` (**Program Listing 2**). Remember, the PIC10F200 microprocessor only has a two level stack, so you've got to be real careful not to make any more than two procedure calls or you'll blow the stack and lose your program. To start timing, you set the **TRM0**

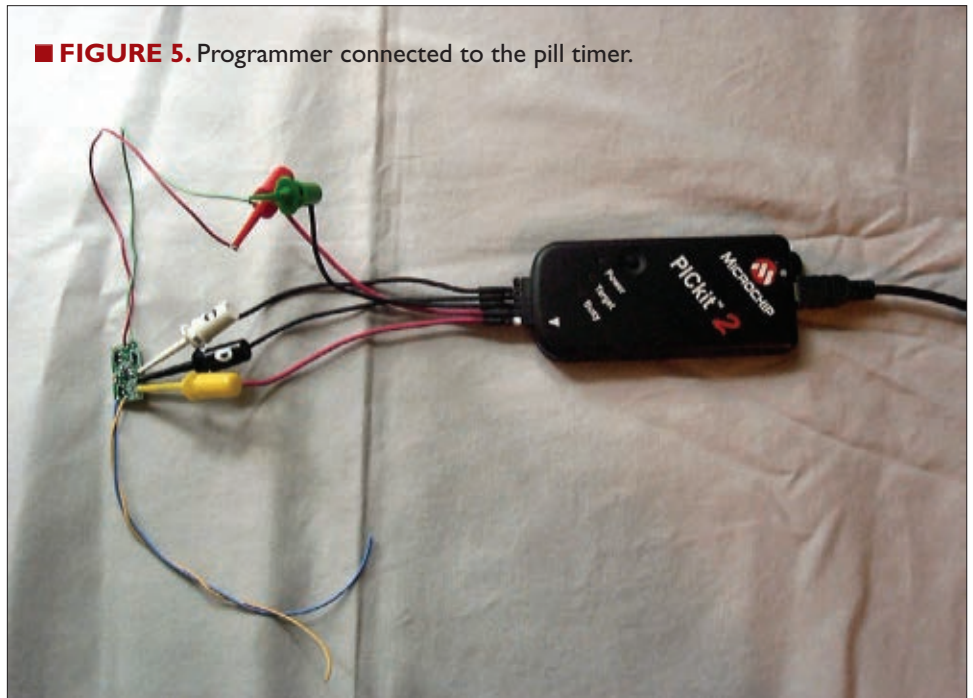
■ **FIGURE 4.** ICD micro clip adapter.



timer register to zero and let it increment through the prescaler. Thus, it will increment once every 256 microseconds until after 255 increments, the eight-bit register will roll back over to zero. The first two code lines set the **TRM0** to zero.

With the **TRM0** register set to zero, we next go to a delay loop (Waitloop) in which we continually read the **TRM0** register and compare it to the count value. If it's not equal, then continue the looping. The counter value 200 gives a delay of 50 milliseconds. When the count value in the **TRM0** register equals 200, then program flow returns from the subroutine. Note that the program cannot do anything else during this delay. So, if your program

■ **FIGURE 5.** Programmer connected to the pill timer.



Program Listing 1 – Set Option Register.

```

;configure uP to use internal timer and pre scaler
MOVLW B'10000111' ;set option bits for TMR0 with osc prescaler
OPTION           ;load option value into OPTION register to configure
;

```

Program Listing 2 – 50 Millisecond Subroutine.

```

Dly50ms; Time delay of 50 milli sec

; DOCODE

    MOVLW    0x00    ; set W register to 0
    MOVWF   0x01    ; set TMR0 register to
                    ; zero

; ENDCODE

Waitloop    ;

; DOCODE

    MOVF    0x01, 0    ; move value of TMR0
                    ; register to W reg
    MOVWF   Scratch   ; now move TMR0 value to
                    ; variable Scratch

; ENDCODE

; IF Scratch <> 200 THEN Waitloop
; loop until time is up -> Endvalue is number
; of counts for time

    MOVLW    200
    SUBWF   Scratch,0
    BTFSS   3,2
    GOTO    Waitloop

; RETURN

```

Program Listing 3 – Five Second Subroutine.

```

Do5sec ;

; Timecnt = 0    \ make sure time count is
                  \ set to zero

    MOVLW    0
    MOVWF   Timecnt

; FOR Timecnt = 0 TO 100

    MOVLW    0
    MOVWF   Timecnt
Elbl3

; GOSUB Dly50ms

    CALL    Dly50ms

; NEXT

    MOVLW    100
    SUBWF   Timecnt,0
    BTFSC   3,2
    GOTO    Elbl4
    INCF   Timecnt,1
    GOTO    Elbl3
Elbl4

; RETURN

    RETLW   0

```

requires other actions, then you need a smaller prescaler value and nested counting loops integrated into the other functions you need to do at the same time.

Since we are only needing to delay, then we can sit in a wait loop until we have our desired time interval. Using the timer makes doing exact timing very easy by eliminating multiple counting loops and the sometimes tedious task of calibrating those loops. The counter value for the wait loop is calculated simply by:

$$\begin{aligned} \text{Delay} \\ \text{Count} &= \text{SSSSSSSSSS} \\ &256 \square \text{ uSec} \end{aligned}$$

The desired delay is divided by the timer increment time of 256 microseconds to give the count for the wait loop. Therefore, 50 milliseconds divided by 256 microseconds gives 195.3125, so for an eight-bit value, this rounds off to 195 decimal or C3 hex. Since there is some small amount of program latency, testing gave a more accurate value of 200.

What we want are time delays in five second increments, so now we need another subroutine that counts the number of 50 millisecond delays to give a full five seconds. The procedure Do5sec (**Program Listing 3**) calls the Do50ms delay function and counts the number of 50 milliseconds to give five seconds, which is 100 times. This means a subroutine calling a second subroutine, which gives us our stack level of 2. This means any more subroutine calls risk blowing the program.

We start with a counter register called **Timecnt** and set it to zero. Next, we set up a FOR-NEXT loop which calls the Do50ms subroutine. Each return increments the **Timecnt** register, then checks to see if it equals 100. If **Timecnt** doesn't equal 100, then the program increments the **Timecnt** register and loops to the Elbl3 label to delay another 50 milliseconds. The value of **Timecnt** is compared by subtracting that register from 100 and then testing if the result is zero. When **Timecnt** equals 100 (subtraction equals 0), then the loop branches to Elbl4 to return to the Main program just after the subroutine call.

The main section of the program (**Program Listing 4**)

starts after the initialization section, and after first selecting the output state based on the solder bridge JP1 by reading port G, then testing bit 3. A FOR-NEXT loop calls the Do5sec subroutine to time a delay of five seconds, and counts the desired number of five second intervals to give the desired delay. At the end of that delay, the output is changed to the state specified by JP1. After that, the program goes to the endless loop Asmend, which is the finished state of the program.

Two other programs are included (PT_1xsec.asm and FLASHER.asm) for your use. The first is another timer program that delays in increments of one second. The second is a flasher program that is a low speed oscillator used to turn something like a light on and off continuously. This flasher program started as an exerciser that I used to measure the time period during development, then I remade it into a user program. To change the time interval for the PT_5xsec.asm and FLASHER.asm program, change the equate statement "TimeX5 EQU 1" from 1 to a number from 2 to 255. That means the five second timer can time up to 255 x five seconds or 21 minutes and 15 seconds. For the PT_1xsec.asm, change the equate statement "TimeX1 EQU 10" to a number from 1 to 255, to give a delay of one to 255 seconds.

These assembly programs are compiled using Microchip's MPLAB ICD program which is free and can be downloaded from www.microchip.com. MPLAB is also used to download the program into the microprocessor using the PICkit 2 programmer.

The Circuit Board

Figure 6 shows the circuit board (center left) beside an actual pill that I take daily, so you can see that the board actually is the size of a pill, while **Figure 7** shows the pill sitting over the circuit board. (The corners of the circuit board are just peeking out from under it.) A completed pill timer – including connecting wire leads – is shown in the lower part of **Figure 6**. As you can see, the full circuit uses all surface-mount components.

The single circuit board layout is shown in **Figure 8**, although only the silkscreen and top layer are shown for clarity. There are some lands on the bottom layer, but all components are mounted on top so the completed pill timer can lay flat as I mentioned earlier. This means double-sided carpet tape can be used to mount pill timers in projects.

So that others can easily make their own circuit boards, I designed the timer using the ExpressPCB version 7.0.2 CAD program for designing circuit boards (which is available as a free download at www.expresspcb.com). Using this program, either of the circuit boards can be loaded and then can be modified, or it can be used as-is to order circuit boards. Both boards are laid out in standard format size to allow purchasing ExpressPCB's three boards for \$59 deal. The file1086010.pcb is the design for the single board while the 1086010P.pcb file has the single board repeated 29 times. Using the single

Program Listing 4 – Main Part of Program.

```

Main      ;

;          Scratch = INP(PortG)

          MOVF   PortG,0
          MOVWF  Scratch

;          ON Scratch  3 TRUE DO SetLo

          BTFSC  Scratch,3
          CALL   SetLo

;          ON Scratch  3 FALSE DO SetHi

          BTFSS  Scratch,3
          CALL   SetHi

;          FOR Timeblk = 1 TO TimeX5
;          ` count the number of desired 5 second intervals

          MOVLW  1
          MOVWF  Timeblk
Elb11

;          GOSUB Do5sec

          CALL   Do5sec

;          NEXT

          MOVLW  TimeX5
          SUBWF  Timeblk,0
          BTFSC  3,2
          GOTO   Elb12
          INCF   Timeblk,1
          GOTO   Elb11
Elb12

;          Scratch = INP(PortG)

          MOVF   PortG,0
          MOVWF  Scratch

;          ON Scratch  3 TRUE DO SetHi

          BTFSC  Scratch,3
          CALL   SetHi

;          ON Scratch  3 FALSE DO SetLo

          BTFSS  Scratch,3
          CALL   SetLo

;          END

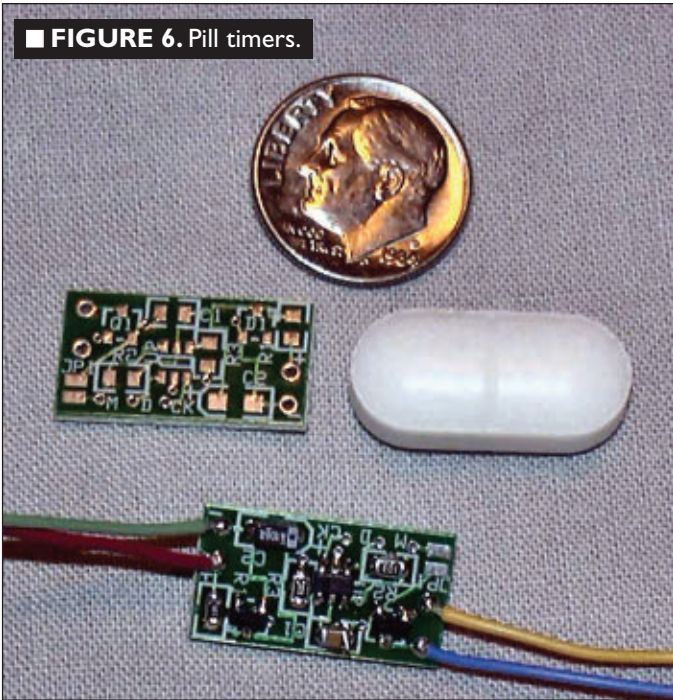
          GOTO   Asmend

```

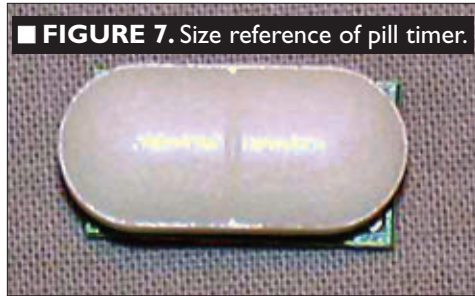
board design means three boards for \$59, so each pill timer circuit board costs \$19.66. Ordering the boards with 29 circuits brings the cost down to 68¢ each.

You will need a shear to cut the individual boards out, so if you don't have a shear, then you need to do a layout where you can cut the boards out without cutting and for

■ FIGURE 6. Pill timers.



■ FIGURE 7. Size reference of pill timer.



between the square pad and the thru-hole is the same as before, then it should still be easy to solder a short across them.

A thru-hole would allow port GP3 to be used as an input for such things as trigger or gating signals. This port pin already has a pull-up resistor, so connecting input signals would be really easy. This input would allow the pill timer to be used for one shot applications, using the basic components in the provided programs to write a new program. Even without the thru-hole, a wire can be carefully soldered to the present pad to give an input signal.

Building the Pill Timer

The downside to building pill timers is it's all surface-mount technology. However, if you haven't done a project with surface-mount components, then this will be a nice little project to start with. Since the gap between pads for the PIC10F200 is only about 0.024 inches; you will need a needle-point tip for your soldering iron. This part is the most difficult to solder in-circuit because it's easy to get a solder bridge between the microprocessor's pins. The remaining parts are large enough and there is sufficient spacing that soldering is easy.

When soldering surface-mount parts, I find it's best to glue each part in place, so there isn't any slipping around while trying to hold your soldering iron in one hand and the solder in the other. (Commercial fabricators glue the parts down prior to soldering.) I use a two-part epoxy called J-B Weld (part number 8265-S) found in most hardware and auto supply stores. This stuff can be used to repair an engine block, so it doesn't have problems with heat. To use, I mix just a dab, then use a toothpick to place just a pin point of glue where the component goes. Then using tweezers, I place the component on the glue spot where it will be soldered. The glue needs to set

several hours before soldering; I usually wait overnight. Don't use so much glue that it squeezes out and covers the surfaces to be soldered, since that will prevent the solder from making electrical contact.

Once the parts are soldered on, connect the programmer adapter and PICkit 2 programmer to the pill timer and download the program to the microprocessor. Now, solder on your lead wires and add it to your project.

Using the Pill Timers

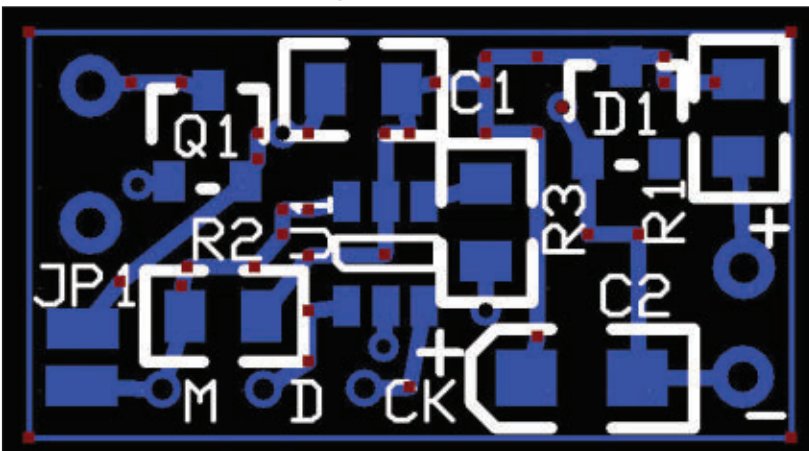
So, what can you do with your pill timer?

damaging the actual circuit board. That's why the single board design is included, so you can copy and paste it into a multi-board design with sufficient spacing to cut everything out. That is, have the width of the cutter blade between each circuit board.

Note that these prices are for circuit boards without the silkscreen and solder mask, and while useable, great care must be taken when soldering parts on. I ordered my three boards with the silkscreen and solder mask so the cost was \$86 for three boards, making the cost per board about a dollar each. (Not bad for high quality circuit boards, except it may take you a while to use 87 of them.)

Although I didn't make any improvements to the circuit board layout, there are two things that I would now do differently. First, I'd make the three holes for connecting the ICD a little larger to make connections easier. Second, the lower pad of JP1 would be a thru-hole the same size as used to mount the lead wires. If the gap

■ FIGURE 8. Circuit board layout.



Well, here are some examples of how you can use them. For turning on/off a motor or light drawing more than 600 mA, you will most likely need some power control device such as a relay. A relay with a coil drawing less than 600 mA and a drive voltage less than 15 volts can be directly connected to the output of the pill timer as shown in **Figure 9**. Don't forget to include a diode across the relay's coil to prevent voltage spikes when the relay is turned off. These voltage spikes can easily destroy the drive transistor Q1. The diode is placed with its cathode on the positive output side of the pill timer so that it is reversed-biased. If you put the diode in backwards, don't worry. When you apply power, the diode will send you a nice little smoke signal that it's in backwards. Start over with a new diode.

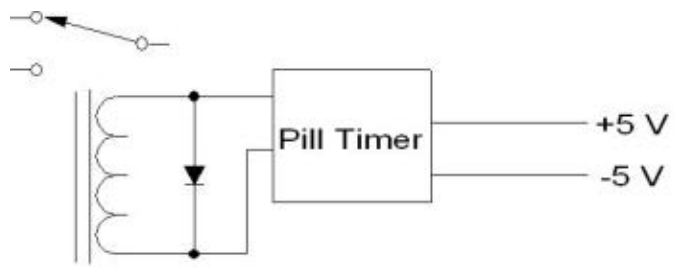
Another neat device for controlling electrical power are AC electronic relays that use semiconductors to turn the power on and off. Electronic relays are very affordable, are controlled with a DC voltage signal level, and can switch as much as 220 volts at 20 amps. Referring to **Figure 10**, the pill timer requires a pull-up resistor across its output (1K to 10 Kohms) to generate the digital control signal necessary to control the electronic relay. The relay's positive input is connected to the resistor on the side of transistor Q1, while the negative input goes to ground (negative power input, or -5V on **Figure 10**). Remember, in this configuration, the sense of the output is reversed.

Something that many electronic hobbyists want to control are LEDs. Looking at **Figure 11**, the LED is connected in series with a limiting resistor to the pill timer, making sure the anode end of the LED is toward the positive output of the timer. LEDs can be strung together in series using a single limiting resistor, as long as the output voltage is sufficient. The limiting resistor should limit current to a maximum of 20 milliamps. Assume each LED has a voltage drop of two volts. LEDs can also be in parallel, but you'll need a limiting resistor for each LED.

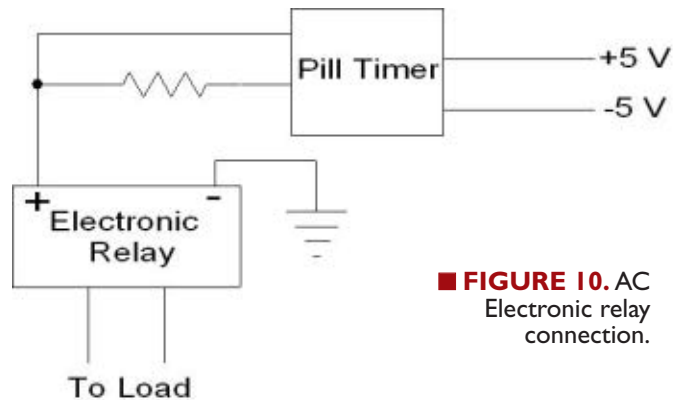
One helpful fixture I made for testing the software in pill timers is shown in **Figure 12**. It provides easy connections to the world. Power is provided by a nine volt battery with an LED to show that power is on. An LED with a limiting resistor is connected with a jumper plug, and another jumper plug is connected to JP1 on the pill timer to allow easy shorting of the startup sense. Finally, a six-pin header is installed to allow the PICkit 2 to be directly installed, making for easier software development.



■ **FIGURE 11.** LED connection.



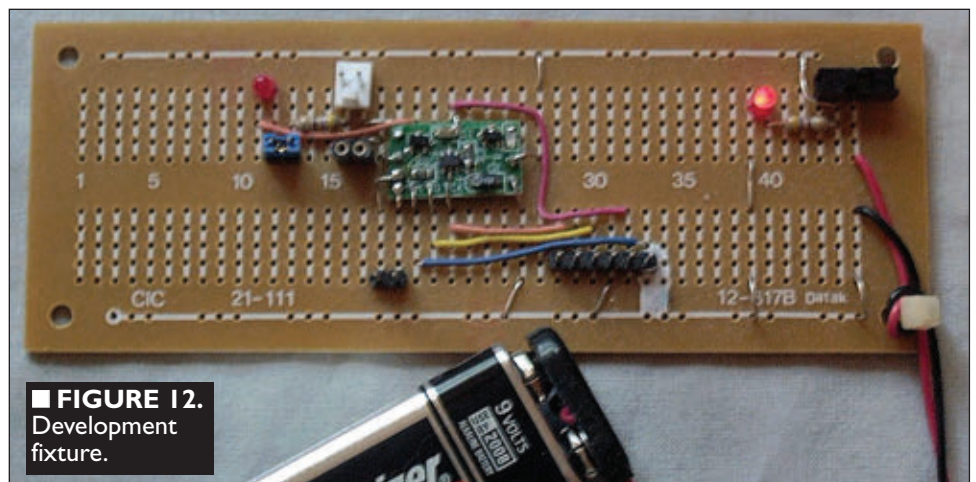
■ **FIGURE 9.** Traditional relay connection.



■ **FIGURE 10.** AC Electronic relay connection.

The files for the three assembly programs and the circuit boards are available for downloading at the article link. Readers can make any changes to any of these files for private use, but may not use any of these materials in commercial products or for resale.

From a software standpoint, what you can do with a pill timer is largely limited by your imagination. Although the program space of the PIC10F200 is small, there is still a lot of capability to do many things, expanded by also being able to use a control input signal. But, the neatest thing about pill timers is their size and being able to stick them into almost any place with a piece of double-sided tape. Making little displays for the holidays becomes a snap, so enjoy this new medicine for curing the headaches in your projects. **NV**



■ **FIGURE 12.** Development fixture.

Review

By Bryan Bergeron

[www.nutsvolts.com/index.php?/
magazine/article/december2011_
Bergeron](http://www.nutsvolts.com/index.php?/magazine/article/december2011_Bergeron)

The SparkFun ProtoSnap Pro Mini

“Whether you’re new to the Arduino or an old fan, the ProtoSnap Pro Mini is worth exploring.”

One of the great things about open source hardware — such as the Arduino — is competition and variety. A quick search on the Internet will reveal Arduino-compatible boards that are smaller, faster, cheaper, or more feature-laden than those offered by rivals. It’s the same for add-ons and books — there seems to be no end to inexpensive sensors and other add-ons from China and books from publishers in the US and EU.

This is a review of the ProtoSnap: an Arduino-compatible board from SparkFun Electronics (www.sparkfun.com). There’s a great tutorial on the \$45 board at the SparkFun website, complete with close-ups of the board and source code. As you can see from **Figure 1**, the little board — which easily fits on the active screen area of an iPhone — consists of a Pro-Mini 5V/16 MHz microcontroller, a USB interface pad, a button pad, light sensor pad, RGB LED pad, buzzer, and prototyping pad.

Why ProtoSnap?

Of all the Arduino-compatible boards, why consider

the ProtoSnap? After all, it’s not the cheapest or fastest board on the market, but it’s perfect for the budget-minded novice. It’s perfect for beginners because there’s no need to hook anything up, other than the USB cable to your PC, Mac, or Linux box. You can experiment with the microprocessor, the buzzer, LED, light sensor, and button without going for a soldering iron or solderless breadboard kit. The USB cable supplies power and enables you to download code to the microprocessor.

In a way, the ProtoSnap is much like a project board with a dedicated processor. These boards typically feature a large solderless breadboard area with microprocessor, sensors, and other devices mounted on the periphery of the board. You can’t do much with these boards without first connecting the pins of the microcontroller to the components with jumper wires.

From a budgetary perspective, traditional project boards are fine for prototyping, but not for deployment. You might extract the microcontroller — assuming it’s not integrated in the board — but you’ll have to purchase a new board and sensors for actual use. With the ProtoSnap, once you’ve figured out your design and programmed the microcontroller, you simply snap the components free and use the pads you need for your project. Of course, the economics of this equation depend on whether your project calls for a buzzer, LED, light sensor, and/or pushbutton.

Board Check

When you first attach a USB cable to the FTDI

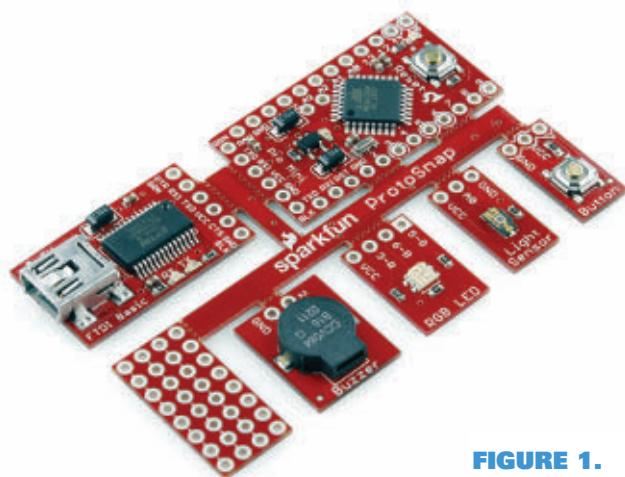


FIGURE 1.

SIDEBAR 1.

```

/*
RGB LED Sequencer for ProtoSnap Pro
Mini
Bryan Bergeron
*/

int button = 7;
int beatcount = 0;
int red = 3;
int blue = 6;
int green = 5;

void setup()
{
  Serial.begin(9600);
  pinMode(red, OUTPUT);
  pinMode(green, OUTPUT);
  pinMode(blue, OUTPUT);
  pinMode(button, INPUT);
}

void loop()
{
  if(digitalRead(button) == LOW)
  {
    beatcount = beatcount + 1;
    if (beatcount > 3)
    {
      beatcount = 0;
    }
    delay(250);
  }
  switch (beatcount){
  case 0:
    digitalWrite(red, LOW);
    digitalWrite(green, LOW);
    digitalWrite(blue, LOW);
    break;
  case 1:
    digitalWrite(red, LOW);
    digitalWrite(green, HIGH);
    digitalWrite(blue, HIGH);
    break;
  case 2:
    digitalWrite(red, HIGH);
    digitalWrite(green, LOW);
    digitalWrite(blue, HIGH);
    break;
  case 3:
    digitalWrite(red, HIGH);
    digitalWrite(green, HIGH);
    digitalWrite(blue, LOW);
    break;
  }
}

```

interface pad, you might be startled to see the RGB LED cycle through red, green, and then blue. According to the documentation in the 50-line source code (also available on the SparkFun website), the LED is intended to cycle when the light sensor is in the dark. I suppose my workbench isn't illuminated as brightly as it could be. I verified the function of the light sensor by bringing my work lamp closer to the board. The LED stopped cycling.

Depressing the button activates the buzzer which is pleasantly subtle, as buzzers go. Some of the buzzers that ship with evaluation boards are loud enough to cause hearing loss. The demo source code is typical Arduino which means it's easy to read and modify. I changed the sensitivity of the light sensor so that it triggered on less light. It's a bit odd that the LED — which is surprisingly bright — is located immediately adjacent to the light sensor.

If you work the button with the LED active, you'll recognize one aspect of the Arduino code: the sensor handling is sequential. If the processor is handling the button down and buzzer, it can't cycle the LED. As a project, see if you can make the buzzer sound whenever the button is pressed.

Note that the board setting for the ProtoSnap is "Arduino Uno." If you set the set the board to "Mini Pro", (as I did), you'll find the microcontroller unresponsive.

Next Steps

Once you've worked through the sample source

code, you should be ready for your first real project. Take a look at the sample code available within the Arduino development environment, under 'Examples'. Most of these examples don't require sensors or pushbuttons. A good first step would be to integrate the sensors and buzzer with the example code. Of course, there's nothing like working on your pet project.

As a 'rhythm-challenged' student of the electric guitar, one of my long-time plans has been to construct a foot pedal that sequences light to silently indicate how closely I'm keeping time with my foot. That is, say, white on beat one, red on two, green on three, and blue on four. I'd associate a handful of high power LEDs with each beat.

The little ProtoSnap kit was just the thing to get me working on this project. The pushbutton is a perfect prototype for a foot button, and the RGB LED was just the thing to prototype the planned array of red, green, and blue LEDs.

The code (shown in **Sidebar 1**) is simple enough. Start by initializing variables. Then, set up the input (button) and output (LED) pins. The main loop consists of reading the button which is LOW when depressed. A button press increments the beatcount variable by one, and the switch statement illuminates the R, G, or B, or all three components, depending on the value of beatcount.

The most interesting line of the code is:

```
Delay(250);
```

This line provides signal conditioning for the

pushbutton, in the form of a 250 ms delay following the first button press. Because the switch contacts bounce when they first make contact, the button doesn't go from open to closed, but opens and closes several times after the initial press. Without the delay, the beatcount variable could be incremented dozens of times by a single button press. There are, of course, more sophisticated button signal conditioning routines, but this one works well for a simple on-off button.

Another way to handle the contact bounce problem is to insert a low pass filter — in the form of a resistor and capacitor — in line with the switch. The simple RC filter — while saving a line of code — is relatively expensive if you consider the components, PC board real estate, and the time to insert and test the components. Furthermore, if you change the switch to another brand or model, the RC filter components may need to be changed to handle the bounce characteristics of the new switch. Changes in software, on the other hand, are trivial.

That's it. My prototype is just about done. My next step is to use the prototyping area to install three small solid-state relays. I'll energize the relays instead of the RGB LED, and have a way to control the much more powerful and power-hungry banks of LEDs that I'm building for the project. I could snap off the microcontroller, add a battery supply, and wire in a foot pedal switch, but I think I'll leave the assembly intact for my next prototype. It's handy

having a three-mode LED and switch to work with, without having to dig for wires or my soldering iron.

Room for Improvement

Nothing's perfect, and every electronics product is designed to provide a list of features at some price point. In this case, the only real area in need of improvement is the USB interface pad. The interface works fine, but once you unsnap the pad from the microcontroller, you'll have to take out your soldering iron to reconnect the two if you want to reprogram the microcontroller. It's a simple enough task to install headers on the microcontroller and USB pad, but you'll need to think ahead and order the parts when you buy the ProtoSnap. Also, you'll need to supply a mini USB cable.

Bottom Line

Overall, this is a great product for beginners — especially beginners without an inventory of parts. I can easily see this used in the classroom, where the teacher doesn't have to contend with keeping track of components, wires, and other parts. The ProtoSnap offers a lot in an affordable compact package, and the design makes it painless to move from prototype to product.

NV

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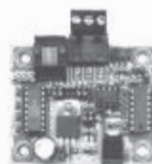
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- 12VDC
- Suitable for power or sail
- Could be powered by a solar panel/wind generator
- PCB: 78 x 104mm

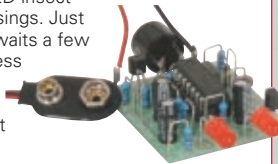


Clifford The Cricket Kit

KC-5178 \$12.50 plus postage & packing

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

- PCB, piezo buzzer, LDR plus all electronic components supplied
- PCB: 40 x 35mm



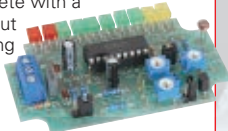
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- 12VDC
- PCB: 74 x 47mm



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Theremin Synthesiser Kit MkII KC-5475 \$54.00 plus postage & packing

The ever-popular Theremin is better than ever! From piercing shrieks to menacing growls, create your own eerie science fiction sound effects by simply moving your hand near the antenna. It's now easier to build with PCB-mounted switches and pots to reduce wiring to just the hand plate, speaker and antenna and has the addition of a skew control to vary the audio tone from distorted to clean.

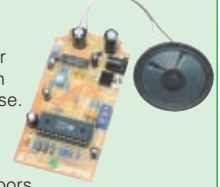
- Complete kit contains PCB with overlay, pre-machined case and all specified components
- PCB: 85 x 145mm



Starship Enterprise Door Sound Emulator Kit KC-5423 \$29.00 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



SD/MMC Card Web Server In a Box

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Host your own website on a common SD/MMC card with this compact Web server In a Box (WiB). Connecting to the Internet via your modem/router, it features inbuilt HTTP server, FTP server, SMTP email client, dynamic DNS client, RS232 serial port, four digital outputs and four analogue inputs. Requires a SD memory card, some SMD soldering and a 6-9VDC adaptor.

- Kit includes PCB, case and electronic components
- PCB: 123 x 74mm



Vehicle G-Force Meter Kit

KC-5504 \$36.00 plus postage & packing

Measure the g-forces on your vehicle and it's occupants during your next lap around the race circuit, or more sensibly use this kit to encourage smoother driving to save petrol and reduce wear & tear. Based around an accelerometer IC, this kit displays the forces (+/- 2g) on the 4-digit LED display. It is not limited to cars either; use it to measure g-forces on a boat crashing over waves or on a theme park thrill ride. Kit includes PCB with pre-mounted SMD component, pre-programmed microcontroller and all onboard electronic components.

- Requires 2 x AA batteries
- PCB: 100(L) x 44(W)mm

Note: To make the kit more accessible to everyday hobbyists we are supplying the PCB with the SMD component already mounted on the board to save time and frustration.



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Short Circuits - Volume 1

This volume will teach you everything you need to get started in electronics and is suitable for ages 8+. We give you the option of buying the book on its own, or together with the accompanying kit that contains the components for each of the 20-odd projects described in the book. Some of the exciting projects include a Police Siren, Electronic Organ, Sound Effects Unit, Light Chaser and many, many more! The full color 96 page book, is lavishly illustrated with over 100 drawings and diagrams. No prior knowledge of electronics is needed, projects are fun and safe to build.

Short Circuits Book
BJ-8502 \$7.25

Short Circuits Project Kit
KJ-8504 \$24.50

Short Circuits Book and Project Kit
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Jaycar Electronics

This circuit lets you simulate the sounds of an English police siren by creating two different tones with a pushbutton switch.

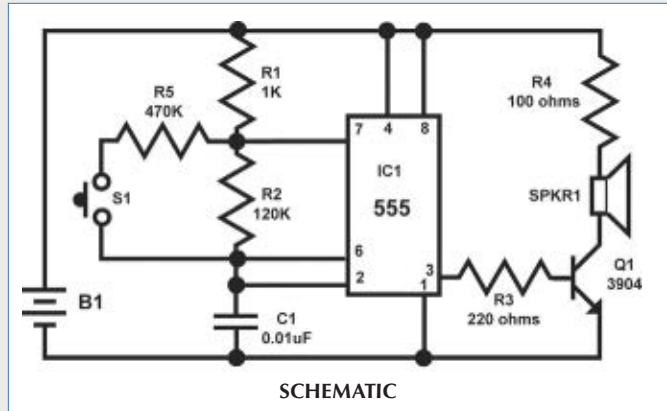
1. Build the Circuit.

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

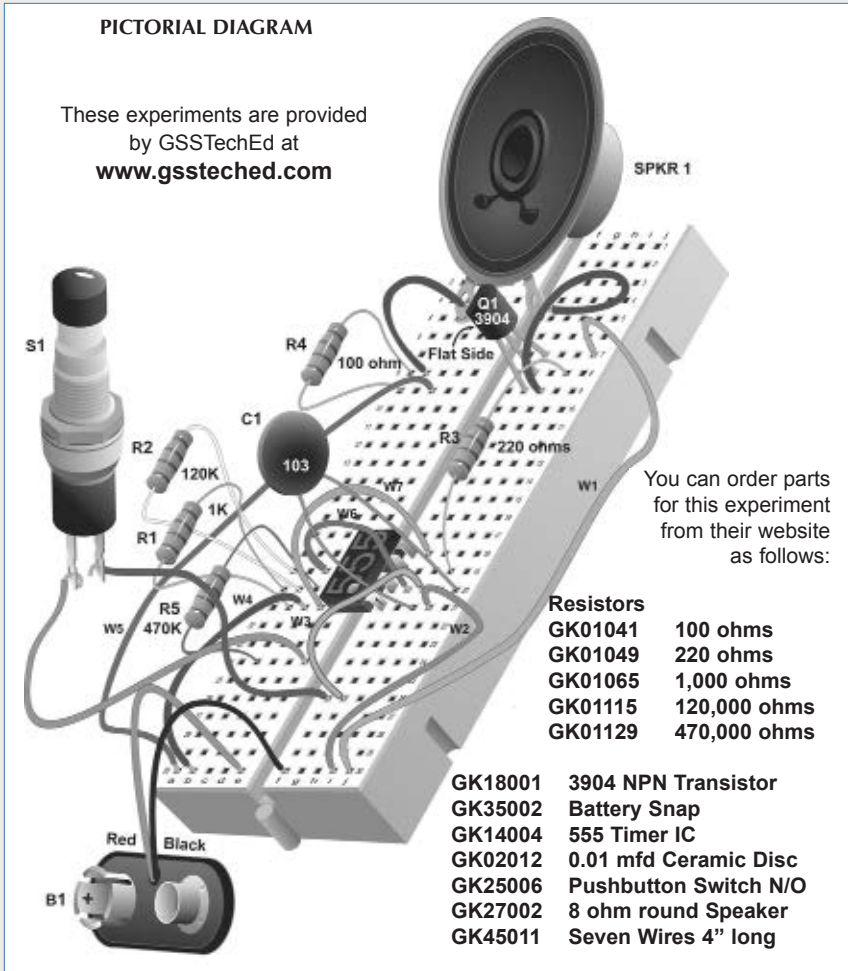
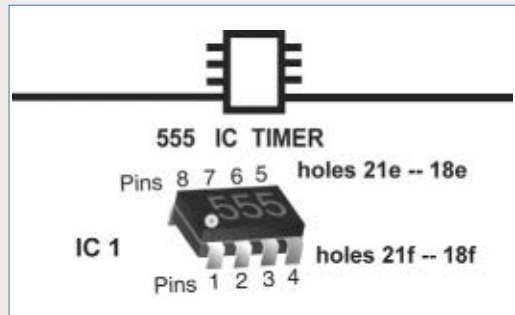
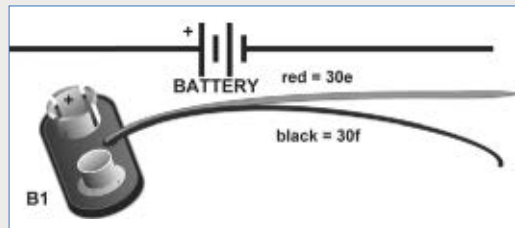
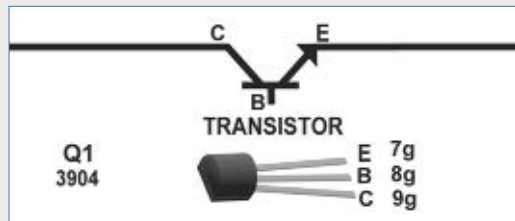
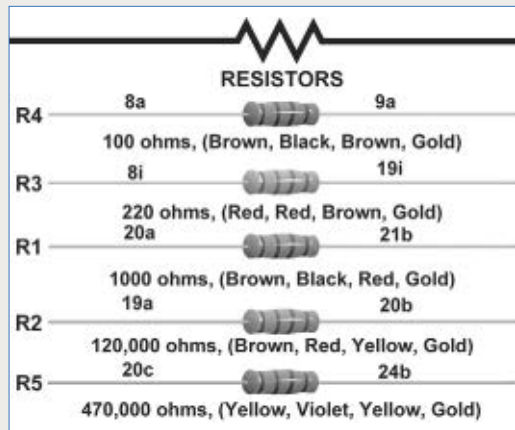
2. Do the Experiment.

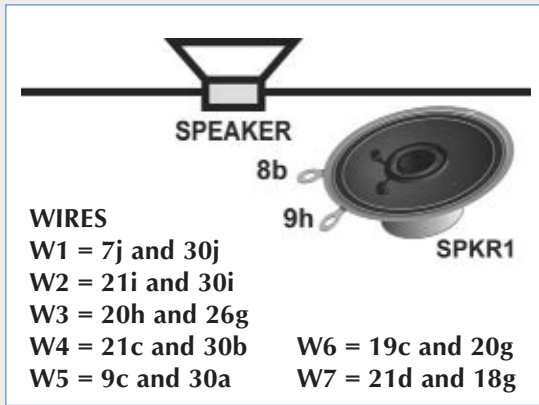
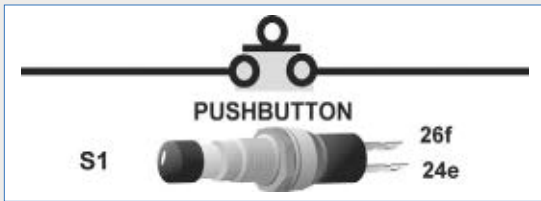
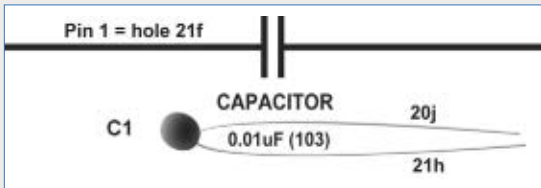
Theory: Here we have a 555 timer IC working as an astable or free-running multivibrator. As we change the voltage across pins 6 and 7, we change the frequency of the output pulses. The time it takes to charge and discharge capacitor C1 determines the output frequency from pin 3. Pressing pushbutton switch S1 causes R5, 470K ohm, to be put in parallel with resistor R2. This, in turn, changes the voltage across these two pins and that changes the frequency of the output pulses coming from pin 3. These output pulses are then sent to transistor Q1 and amplified. This amplified signal is then sent to the speaker.

Procedure: Connect a nine volt battery to the battery snap. You should hear a tone. If you press the pushbutton switch, you will hear another tone. As you press and release the pushbutton switch, you'll be able to create the sounds of a two-tone English siren.



SCHEMATIC





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■ BY LOUIS E. FRENZEL W5LEF

BUILDING A CRYSTAL RADIO Really? Is This A Sane Thing To Do?

Who in their right mind would want to build a crystal radio (or crystal set as it is sometimes called)? A crystal radio is the absolutely simplest radio there is and is, in fact, the very first communications receiver. It derives its name from the detector or diode used in detecting the radio signal. The original diode was a piece of crystal called galena. When you made contact with it by way of a small wire probe, you created a diode in which current would easily flow through it in one direction and not flow in the other direction. This crystal acted as a diode that performed rectification. Rectification is the process of converting AC to DC, and for detection or demodulating AM radio signals. Today, the crystal is a semiconductor diode made of the semiconductor material germanium.

With a crystal diode, a tuned circuit, and an earphone, you can make a radio that receives AM (amplitude modulation) radio stations. The big question remains, why do that? In today's high tech world of iPhones, satellite TV, MP3 players, and the Internet, why revert to such an anachronism? Who listens to AM radio today, anyway?

Some good reasons to build a crystal radio are, first, as a learning experience. If this is your very first electronic construction project, it is a good one. It uses very few components and they are very easy to connect. Second, it

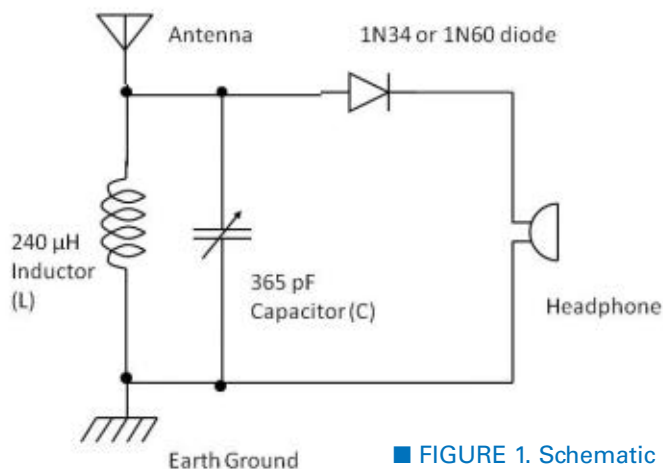
is a good educational project. You learn about resonant circuits, diode rectification, and soldering.

As for who listens to AM radio, you would be surprised. If you listen to the radio for music, then you probably listen mostly to FM. But millions still listen to AM for news, weather, traffic, and general talk radio shows. You can still hear lots of music on AM, as well. There are roughly 5,000 AM radio stations around the country in even the smallest of towns. As old as it is, AM radio is not going away anytime soon.

I built my first AM radio decades ago. It was, in fact, my first actual electronic construction project. And it really worked. I credit that experience to putting me on the path to a long career in radio and electronics. Recently, I had the urge to build a crystal radio again. Mainly just to see if I could and what I could hear. This project was an attempt to recapture those simpler days of radio and electronics. If you have never built a crystal radio, you may want to give it a try.

HOW IT WORKS

Figure 1 shows the schematic diagram of a basic crystal radio. An inductor or coil (L) is connected to a variable tuning capacitor (C), and those are connected to a diode in series with an earphone. An antenna is connected to one end of the coil and a ground is



■ **FIGURE 1.** Schematic of the crystal radio.

■ **FIGURE 2.** The complete crystal radio. The coil is on the left. Only one section of the capacitor on the right is used. You can see the diode between the coil and capacitor. The black wire with the alligator clip on the right goes to Earth ground. The antenna connects to the right end of the diode where it is soldered to the capacitor.

connected to the other end of the coil. By tuning with the capacitor, you should pick up one or more AM radio stations.

The coil and capacitor together create a tuned or resonant circuit. You can calculate the resonant frequency from the formula:

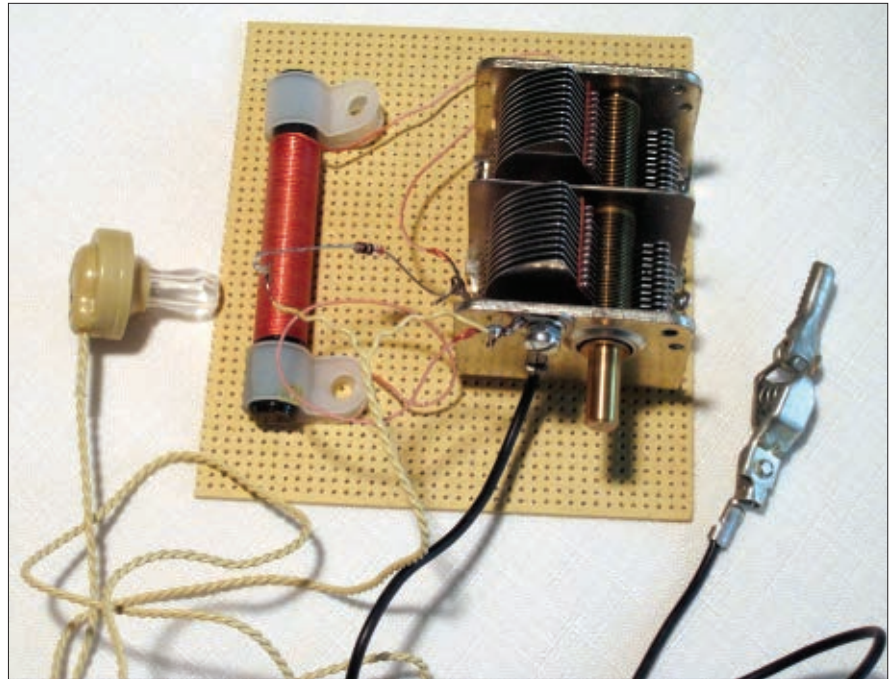
$$F = 1/2\pi\sqrt{LC}$$

F is the frequency in Hertz (Hz) or cycles per second; L is the inductance in henries; and C is the capacitance in farads. You select the values of L and C to tune to the AM radio band which is from 530 to 1,700 kHz. A typical value of inductance is about 240 microhenries (μH). This matches up with a variable capacitor with a capacitance tuning range of about 30 to 365 picofarads (pF).

The resonant circuit is connected to an antenna. The antenna picks up the radio signal and converts it into a voltage. The voltage appears between the antenna and Earth ground. The tuned circuit responds to that signal. When the circuit is tuned to a station, it becomes resonant at that frequency and has maximum current flowing thanks to the process of resonance. The result is a signal to the diode.

The diode rectifies the AM signal. The AM radio signal is an alternating current (AC) voltage that oscillates or regularly reverses polarity at the station's frequency. The diode chops off one half of the signal making it a DC variation. The amplitude of the DC variation is the AM signal being transmitted — either voice or music. This rectified signal is applied to an earphone. The earphone cannot respond to the high frequency AM signal variations, but it does average their peaks into the original audio voice or music signal.

■ **FIGURE 3.** Two inductors. The one on the left is the commercial model, while the one on the right is obviously homemade. Both are four inches in diameter and have an inductance of 240 microhenries.



BUILDING THE CIRCUIT

You don't need many parts for this project. You can buy them from several sources. I bought mine from Crystal Radio Supply (www.crystalradiosupply.com) but other sources are available. **Figure 2** shows the complete rat's nest circuit.

The inductor is essentially just a coil of wire. The inductance should be about 240 μH . I found two good ones; a small coil wound on a ferrite core as shown in **Figure 2** and a second one that is a larger air core coil as





shown in **Figure 3**. Both work well, but the ferrite core coil has a higher Q which provides somewhat better performance. Q is the quality factor of the coil which is a measure of how efficient the coil is. The higher the Q, the better the results. You can also make your own coil. I made one using plain old #22 copper wire wound on a four inch diameter form; in this case, a box of grits. An oatmeal box is a good alternative since both are four inches in diameter. Use 40 turns of wire closely spaced. Punch holes in the box to secure the wire at the ends. You may need to glue them down to hold the coil in place and keep it from unwinding. Be sure to scrape the enamel insulation from the wire ends before you solder it.

You are probably going to have to buy the variable capacitor. These were once widely available in every model AM radio but no longer. Again, I bought mine from Crystal Radio Supply, but I also found one at www.stormwise.com. The capacitance is typically 365 pF when the plates are fully meshed, and down about 30 pF when the plates are fully unmeshed. The shaft is easy to turn for tuning. The one I bought is shown in **Figure 2**. It is actually two capacitors that are ganged together. You will only need one section. You can also buy a one-section capacitor, as well.

The crystal is a germanium diode. These are no longer widely used but you can still buy them. Part numbers such as 1N34, 1N34a, 1N60, or 1N270 are common. Any of these should work. I used a 1N60. Do NOT substitute a silicon rectifier diode like a 1N4001, 1N914, or 1N4148. It simply won't work. The germanium diodes have a much lower threshold of conduction of about 0.2 volts, compared to about 0.7 volts or so for the silicon diode. Radio signals are very small and if you want this to work, stick with the germanium diode. One possible substitution I did not try was a Schottky or hot carrier diode. These small signal diodes are made for very high frequency and microwave signals, and should work.

Headphones are also important. The widely available earbuds or headphones used with iPods, MP3 players, and other modern audio products have a very low impedance (32 ohms or so). These will load down the tuned circuit, reducing the Q and rendering it inoperable. You must use high impedance (many megohms) crystal or ceramic ear phones.

BUILDING THE RADIO

I did not intend for this to be a final finished project. I just wanted to see if I could do it for nostalgic reasons, I guess. So, I just soldered everything together in a haphazard way as **Figure 2** shows. The only pain in the neck connection was to the capacitor. One side of the capacitor has a nice solder terminal for connecting the coil and diode, but the other connection to the capacitor is the actual metal housing. I found a solder lug in my junk box and screwed it into the capacitor housing with a short 4-40 screw. It is mechanical connection details that

sometimes discourage us from building electronic circuits.

ANTENNA AND GROUND

One thing for sure is that this radio absolutely needs a big antenna to work. The bigger — or longer — the antenna, the more signal it picks up and the stronger the voltage applied to the circuit. This, of course, translates into a louder signal in the earphone. The antenna should be the very longest piece of wire you can afford or place. I used 100 feet of #14 copper wire which I strung on my wooden back yard fence. You may be able to get by with 50 feet but that depends on how strong or how close your local stations are. I tried 20 feet of wire and it did not work; 200 feet would be great if you can manage it. Keep the wire off the ground and as high as possible. This radio will also not work without a good ground. And by ground, I mean the Earth. I used a four foot copper rod from RadioShack. Drive it as far into the ground as you can. I connected the antenna wire to an alligator clip that attaches to the solder connection on the capacitor (not the solder lug). Connect the solder lug on the capacitor to a wire that will attach to the ground rod. I used about 15 feet of #16 speaker wire with an alligator clip to make this connection.

USING THE RADIO

Once you solder everything together, make the connections to the antenna and ground, and you are ready to go. Tune the capacitor slowly while listening on the earphone. You should be able to hear at least one local AM station. The strongest station will stand out. If you have several stations locally, you could hear more. I heard just two: a local station on 590 kHz and one on 1,200 kHz about 70 miles away. This later station is one of those clear channel AM stations transmitting 50K watts.

Just so you won't be disappointed, you should know in advance that the stations you will hear will be very weak. Good hearing is an asset. Also, most AM stations transmit more power during the day than at night, so daylight testing is a must. For greater volume, a longer antenna is the answer. You can also experiment with different components. Try a different coil and see what works best. Try another diode. That may help. If you can find a Schottky hot carrier signal diode (NOT a power supply rectifier diode), give that a try. A 0.001 μ F capacitor in parallel with the earphone may help. I did not notice much difference.

The other possible addition is an amplifier. Adding a one transistor amplifier in place of the headphone will boost signal strength considerably. I did not do that as I wanted to see the pure crystal set performance. It is totally self-powered by the radio signal it receives.

I was pleased with the result of this project. It seemed so silly given the state of technology today, that I questioned my sanity. However, for many of you it could be the beginning of a long hobby or career. **NV**

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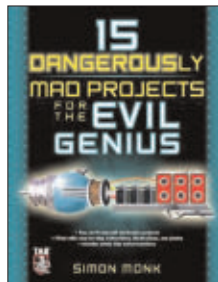
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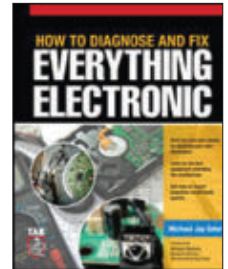
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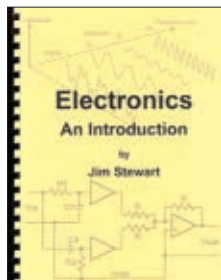


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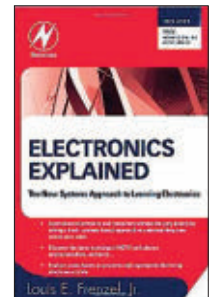
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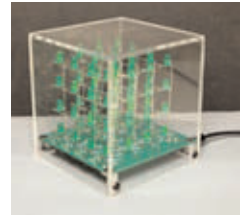
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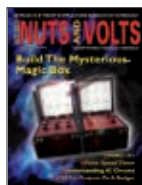


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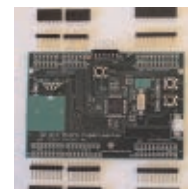


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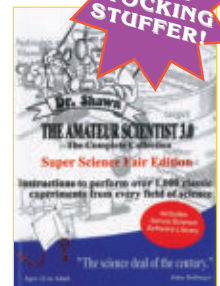
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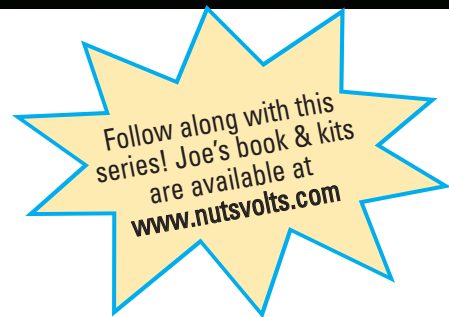


#41 SMILEY'S WORKSHOP

C PROGRAMMING - HARDWARE - PROJECTS

by Joe Pardue

Digital I/O — Part 3 Bitwise Operations



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

Recap

In Part 1 of this series, we looked at the software side of Digital I/O (DIO) as it is done in the Arduino using the sequentially numbered pins on the Arduino board. We wrote a library of functions like the Arduino DIO functions but used regular C concepts and tools (AVRStudio, WinAVR, avrdude, avrlibc, etc.). In Part 2, we saw that the Arduino pins are simple abstractions of the deeper AVR microcontroller's concept of ports that are eight-bit arrays

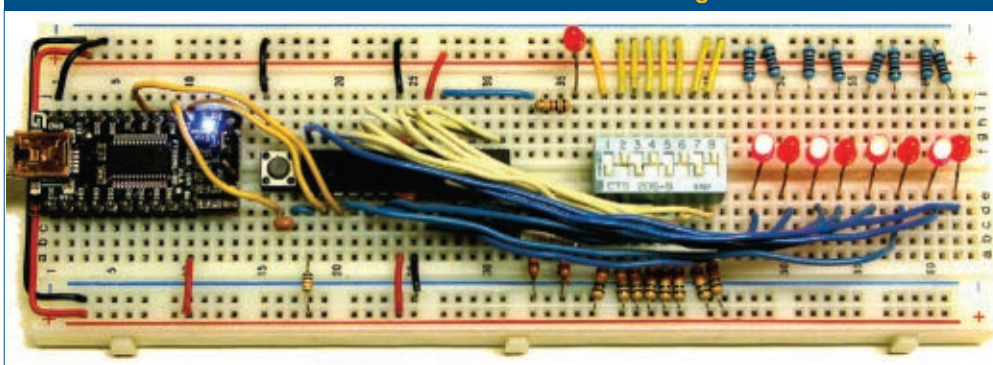
of pins, and then we wrote a library that specifically handles ports and their pins as they are used by raw AVR's. Now in Part 3, we will drop the abstractions and look at how DIO is really done in AVR's using the tools available in C, without having to write special libraries to manipulate the ports and pins for DIO.

So, Part 1 was a high level abstraction for DIO; Part 2 was a mid-level abstraction; and in Part 3, we will look at the raw low level stuff with no abstractions involved. After we see how the professionals do this (yes, it will be on the test), we will (mercifully) build a set of low level macros that will help you do things with DIO without requiring that you be a certified C guru. [BTW, if you know what `PORTB &= ~(1<<PB5)`; does immediately without having to think about it, then you are certifiable.] Since we are determined to get as close to the machine as possible, we will demonstrate the DIO input with an eight-pin DIP switch and the DIO output with eight LEDs using an ATmega328 on a breadboard (as shown in **Figure 1**). We looked at the BreadboArduino in the April '10 *Nuts & Volts* Smiley's Workshop 21 and the details are on my blog: <http://smileymicros.com/blog/2011/06/15/arduino-on-a-breadboard-breadboardino>. A parts kit is available from *Nuts & Volts*.

Operator	Name	Example	Defined
~	Bitwise complement NOT	~x	Changes 1 bits to 0 and 0 bits to 1
&	Bitwise AND	x&y	Bitwise AND of x and y
	Bitwise OR	x y	Bitwise OR of x and y
^	Bitwise exclusive OR	x^y	Bitwise XOR of x and y
<<	Left shift	x<<2	Bits in x shifted left two bit positions
>>	Right shift	x>>3	Bits in x shifted right three bit positions

Table 1. Bitwise Operators

■ FIGURE 1. BreadboArduino chaser lights.



Theory

Bitwise Operators

Bitwise operators are critically important in microcontroller software. They allow us to do many things in C that can be directly and efficiently translated into microcontroller machine

operations. This is a dense topic, so get out a pencil and piece of paper and work through each of the examples until you understand it.

In case you've ever wondered how to tell what is true and what is false, for **bitwise operators** which use binary logic (single bits), 1 is true and 0 is false.

We discussed binary vs. hexadecimal vs. decimal in Workshop 3, but to refresh: A byte has 256 states numbered 0 to 255. We number the bits in a byte from the right to the left as lowest to highest:

```
bit #      76543210
myByte = 01010101 binary = 0x55 hexadecimal
          = 85 decimal
```

Look at the truth tables for AND '&', OR '|', XOR '^', and NOT '~':

AND '&'	OR ' '	XOR '^'	NOT '~'
0 & 0 = 0	0 0 = 0	0 ^ 0 = 0	~1 = 0
0 & 1 = 0	0 1 = 1	0 ^ 1 = 1	~0 = 1
1 & 0 = 0	1 0 = 1	1 ^ 0 = 1	
1 & 1 = 1	1 1 = 1	1 ^ 1 = 0	

Now, memorize them. Ouch, but yes, I am serious.

ORing

We can set bit 3 to 1 in a variable, myByte, by using the Bitwise OR operator '|':

```
myByte = 0;
myByte = myByte | 0x08;
```

To see what's happening, look at these in binary:

```
bit #      76543210
myByte = 00000000 = 0x00
0x08 = 00001000 = 0x08
-----
OR '|' = 00001000 = 0x08
```

We see that bit 3 is 1 in 0x08 and 1 | 0 = 1, so we set bit 3 in myByte.

Suppose myByte = 0xF7:

```
bit #      76543210
myByte = 11110111 = 0xF7
0x08 = 00001000 = 0x08
-----
OR '|' = 11111111 = 0xFF
```

Or maybe myByte = 0x55:

```
bit #      76543210
myByte = 01010101 = 0x55
0x08 = 00001000 = 0x08
-----
OR '|' = 01011101 = 0x5D
```

This shows that only bit # 3 of myByte is changed by the OR operation. It is the only bit equal to 1 in 0x08 and ORing 1 with anything always yields 1, so you can use it to **'set'** a bit regardless of that bit value.

ANDing

Now let's do the same thing with the & operator. We can clear bit 3 with:

```
myByte = 0xAA;
myByte = myByte & 0xF7;

bit #      76543210
myByte = 10101010 = 0xAA
0xF7 = 11110111 = 0xF7
-----
AND '&' = 10100010 = 0xA2
```

Or maybe myByte = 0x55:

```
bit #      76543210
myByte = 01010101 = 0x55
0xF7 = 11110111 = 0xF7
-----
AND '&' = 01010101 = 0x55
```

From this, you see that ANDing with 1 leaves the bit value the same as the original bit, and ANDing with 0 clears that bit regardless of its state, so you can use ANDing with 0 to **'clear'** a bit value.

Setting and clearing bits is very important in AVR microcontrollers since the plethora of peripherals available are set up by either setting or clearing the hundreds of bits in dozens of byte-sized registers.

Setting and Clearing Bits

In each of the above cases, we are only dealing with a single bit, but we might be interested in any or all of the bits. Another important feature of using bitwise operators is that it allows us to set or clear a specific bit or group of bits in a byte without knowing the state of – nor affecting – the bits we aren't interested in. For example, suppose we are only interested in bits 0, 2, and 6. Let's set bit 6, regardless of its present value, then clear bits 0 and 2, also regardless of their present value and – here's the trick – we must leave bits 1, 2, 4, 5, and 7 as they were when we began.

NOTE:

```
myByte = myByte | 0x08;
```

is the same as

```
myByte |= 0x08;
```

which we will use from now on. To set bit 6, we OR myByte with 0100000 0x40:

```
myByte = 42;
myByte |= 0x40;

bit #      76543210
myByte = 00101010 = 0x2A
0x40 = 01000000 = 0x40
-----
OR '|' = 01101010 = 0x6A
```

Next, we want to clear bits 0 and 2 so we AND 11111010:

```
myByte &= 0xFA;

bit #      76543210
myByte = 01101011 = 0x6B
0xFA = 11111010 = 0xFA
-----
AND '&' = 01101010 = 0x6A
```

So, in summary, we set bits with '|' and clear bits with '&.' If you are going 'Oh my gawd!' at this point, I hope it is because you are surprised that you actually understand this. If it isn't, then get that pencil and paper, and go back till you do.

XORing

Suppose we want to flip the highest four bits in a byte while leaving the lowest four alone. We could use a mask with the bits you want to flip set to 1 and the bits you don't want to flip set to 0:

```
myByte = 0xAA;
myMask = 0xF0;

myByte ^= myMask;

bit #      76543210
myByte = 10101010 = 0xAA
myMask = 11110000 = 0xF0
-----
XOR '^' = 01011010 = 0x5A
```

XORing is used a lot in cryptographers, but not a lot by us mortals.

NOTing

Using the above example, we could clear those bits in myByte using the NOT on the mask, then AND it with myByte:

```
myByte = 0xAA;
myMask = 0xF0;

myMask = 11110000 = 0xF0
~myMask = 00001111 = 0x0F

myByte &= ~myMask;

bit #      76543210
myByte = 10101010 = 0xAA
~myMask = 00001111 = 0x0F
-----
AND '&' = 00001010 = 0x0A
```

Shift Operators

The shift operators can be used to radically speed up multiplication and division **IF** you use numbers that are a power of 2. You might want to do this for tasks like averaging ADC readings. When we study ADC, you'll see that sometimes we can get more accurate results if we take a bunch of readings and average them. My first inclination was to take 10 readings and then

divide by 10. I chose 10 because I've got that many fingers, but if I had chosen eight or 16 then my division would be much faster using >>. If I divide by 10, the compiler has to call a large and complex division function and floating-point data types, but if I divide by eight it only needs to shift bits three positions to the right. Three quick right shift operations versus lots of time and program space — the tradeoff is precision.

Let's say my readings were:

54, 62, 59, 57, 60, 59, 56, 63 = 470

The sum is 470 and $470 / 8 = 58.75$

Remember that the largest decimal number that fits in an eight-bit byte is 256, so we must store 470 in a 16-bit integer (0000000111010110):

```
myTotal = 470

bit # FEDCBA9876543210 (in Hex)
myTotal 0000000111010110
```

If we shift this right three times, it becomes:

```
myAverage = (myTotal >> 3);

bit # FEDCBA9876543210 (in Hex)
>> 3 000000000111010110
```

The low three bits (110) fall out of the AVR and have to be swept up later. [You didn't believe that did you? They actually just disappear.] Anyway, the value now (ignoring the leading zeros) is 111010 which is decimal 58. Note that 58 is not 58.75, but you did save both time and program space so you have to decide which is better to use. The binary averaging gets you closer than all but two of the eight readings (59) and it does it lightning fast so if you are time constrained, the tradeoff should be obvious.

The Ternary Conditional Operator

Since we are already in about as deep as it gets, let's look at one last dense thing: the ternary conditional operator. (Don't you just love the way programming concepts get named? Ternary conditional operator, sounds like it means something that a programming guru might spout out in a stream of trying to scare you out of competing with him.) Unfortunately, even though this operator is quite useful it is not only a mouthful to say, but it's a bit of slog trying to get your head around it. It looks like this:

a ? b : c

It says that given the condition 'a,' if that condition is true, then do 'b,' if it is false, do 'c.'

[condition] ? [do this if true] : [do this if false];

A condition is any combination of variables, operators, and function calls that produce a single value. Since this is a logic condition, then any result of 0 is false and any other result is true.

For instance, if you want to turn on a fan if the temperature is above 150° F, or to turn off the fan if it is below 150° F, you could use:

```
temp > 150 ? Fan(ON) : Fan(OFF);
```

The condition: `temp > 150` is evaluated to see if it is true or false. If it's true, then the function `Fan(ON)` is called; if it's false, `Fan(OFF)` is called. At this point, you might be yelling at the page: "Hey, I can do this with an 'if' expression!" You actually could, as follows:

```
if( temp > 150)
    Fan(ON);
else if( temp < 100)
    Fan(OFF);
```

Since one of our goals is to learn C – which sometimes means learning several equivalent ways to do the same thing – you ought to get used to the ternary conditional operator because you will see it a lot, and we will use it in the digitalio library.

Yet Another Really Dumb Error

I like to share my really dumb errors with folks so that they can see that even those of us who ought to know this stuff by now sometimes make embarrassing mistakes. So, what is wrong with the following?

```
value ? (PORTD != (1<<pin)) :
(PORTD &= ~(1<<pin));
```

Well, when you have a bit of presbyopia and are squinting at the screen you may not see the problem. When you write this in your code, the compiler may just incorrectly assume that you know what you are doing and not even give you a warning since what you wrote is perfectly legal in C – but not at all what you intended. The compiler didn't give me a warning and I futzed away a half hour before I finally saw that I'd used a '!' in place of a '|'. IMHO, this is yet another reason to use macros. If I had written this with macros for the set and clear operation, then it would be:

```
value ? pin_set(PORTD,pin) :
pin_clear(PORTD,pin);
```

And I wouldn't have made that typo. In fact, if I get the `pin_set` macro correct, then I'll never make that dumb mistake again. Which neatly brings us to ...

Macros Can Help

If we want to clear the 0 bit in `PORTB`, we write: `PORTB &= ~(1<<PORTB0)`. I'm sorry, but this is just nasty looking. It is the C way of doing things, but listen up my friend because now I'm going to give you some truth. If

you want to be a professional C programmer and get to wag your huge wagging thing that other pros wag, then you not only have to memorize the bitwise operators, you have to use them raw – and you must scoff at folks who use simplifying macros. However, if you are more interested in getting the job done than in wagging your C programming skills at people, then you might want to use a set of simplifying macros that encapsulate all those mind-bending operators into something with a descriptive name attached to them. Like maybe `bit_clear(PORTB, PORTB0)` instead of `PORTB &= ~(1<<PORTB0)`.

So, let's save a few brain cells and write a small header file: `bitwise.h`. That will provide us macros with clear names for these operations. Be sure and note, however, that if you are taking a class on C programming, the teacher will quite correctly make you use the actual operators (and it will be on the test). If you aren't a full time C programmer, then these macros can help to make your life easier:

```
#define bit_get(p,m) ((p) & (m))
#define bit_set(p,m) ((p) |= (m))
#define bit_clear(p,m) ((p) &= ~(m))
#define bit_flip(p,m) ((p) ^= (m))
#define bit_write(c,p,m) (c ? bit_set(p,m) :
    bit_clear(p,m))

#define bit(x) (0x01 << (x))
#define LONGBIT(x) ((unsigned long)0x00000001
    << (x))
```

Masks: Using Named Bits

We sometimes want to look only at a few contiguous bits in a byte or integer. For instance, we might want to only look at the high four bits in a byte. We use a mask with the bits of interest set to 1: `0xF0` (`0b11110000`). We then AND '&' this mask with the byte of interest remembering that the only way we can get a 1 out of ANDing is if both bits are 1. For instance, if we want to extract the number in the top four bits of `myByte` first we AND `myByte` with `myMask`:

```
bit #      76543210
myByte = 10011011 = 0x9B
myMask = 11110000 = 0xF0
-----
AND '&' = 10010000 = 0x90
```

Then, we shift the results right four bits:

```
bit # 76543210
myResult 10010000 = 0x90

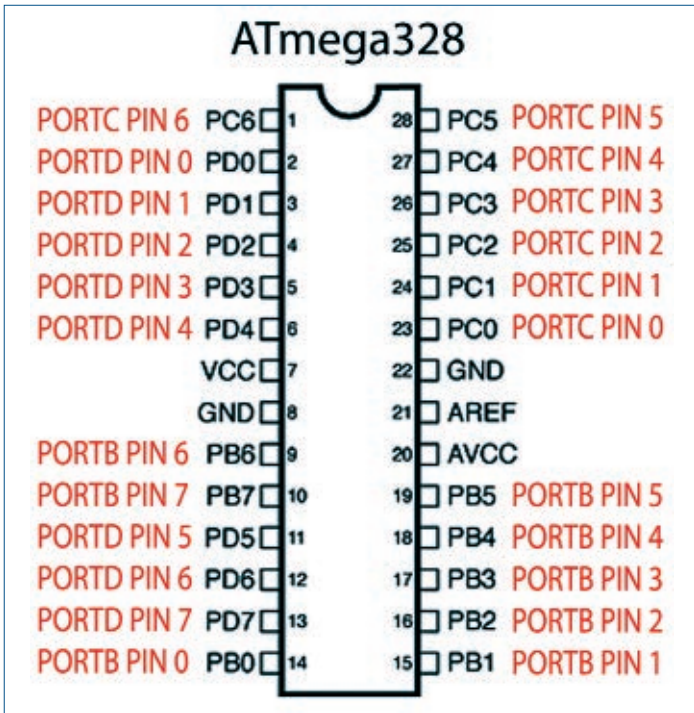
(myResult >> 4);

bit # 76543210
>>4  00001001 = 0x09
```

Lab Section: Using Bitwise Operations

Chaser Lights With the BreadboArduino

All that theory makes my head hurt! To help us feel better, let's make something bright and shiny! And what



■ FIGURE 2. ATmega328 port pin mapping.

is brighter and shinier than LEDs? (Okay, the sun, but who has time to go outdoors when there is so much neat stuff to learn?). Let's design some chaser lights with eight LEDs that allow us to use an eight-pin DIP switch to select 16 sweep patterns, eight speeds, and polarity (more on that later). You can see what this looks like in **Figure 1**, and I'm sorry for the rat's nest of wires. The ATmega328 pins in

Figure 2 and the schematic in **Figure 3** will guide you in creating your own rat's nest.

Getting Bit Fields From a DIP Switch

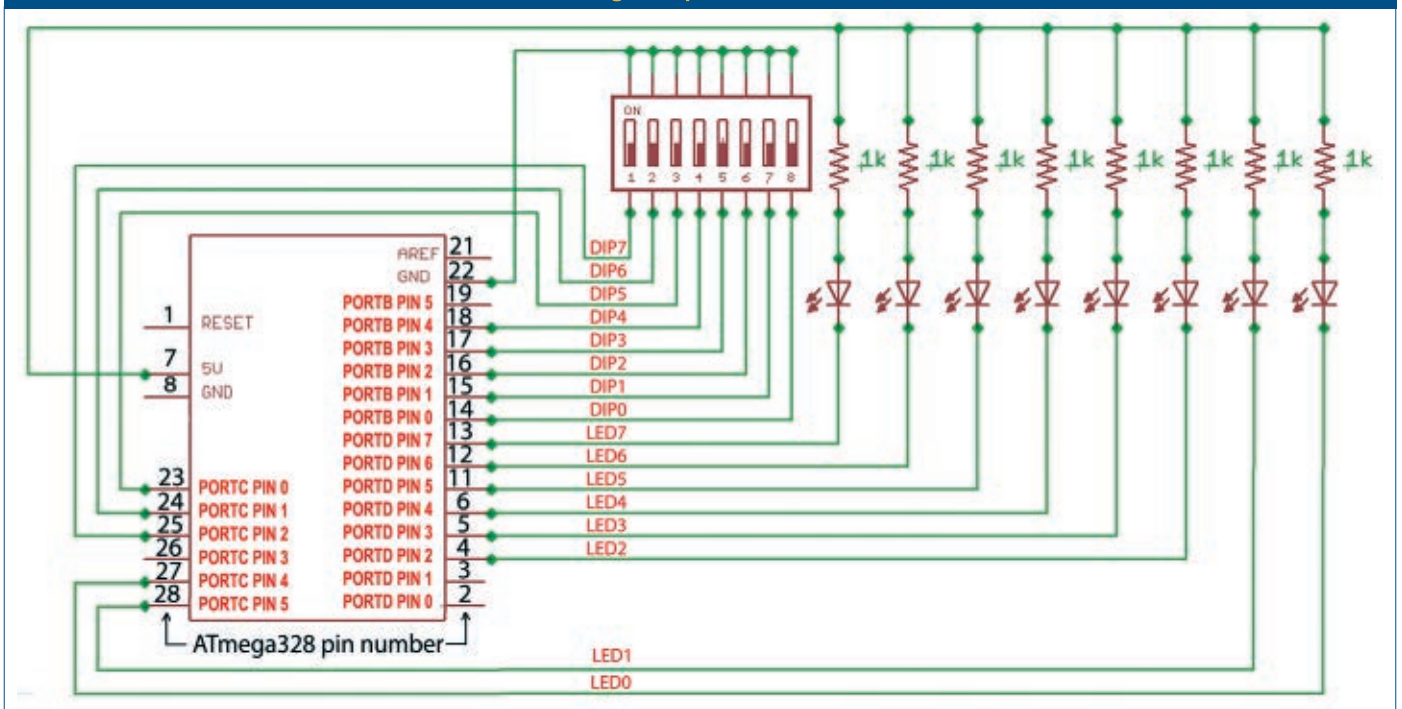
We will let the top four switches encode 16 patterns, the next lower three can encode eight speeds, and the lowest switch can encode the polarity. In order to look at each of these parameters individually (while ignoring the others), we use bit masks which are sets of bits set to 1 that we AND '&' with the byte so that we exclude the other bits. This is best explained with an example:

```
// DIP switch masks
#define POLARITYMASK      0x01      // 00000001
#define SPEEDMASK        0x0E      // 00001110
#define PATTERNMASK      0xF0      // 11110000
```

We have eight patterns and we can encode them with four switches, as follows:

Binary	Decimal	Pattern Select
0000	0	right_sweep1
0001	1	right_sweep2
0010	2	right_sweep3
0011	3	right_sweep4
0100	4	left_sweep1
0101	5	left_sweep2
0110	6	left_sweep3
0111	7	left_sweep4
1000	8	right_stack
1001	9	left_stack
1010	10	right_ant

■ FIGURE 3. ATmega328 pins for DIP switch and LED.



1011	11	left_ant
1100	12	inout
1101	13	blinkin
1110	14	brownian
1111	15	random

[NOTE: For sweep 5, 6, and 7, just run sweep 1, 2, and 3 with the polarity reversed.]

If we AND each of these masks with the value we read on the DIP switch, we convert all the bits we aren't interested in to 0 and leave those we are interested in as they were in the port. Suppose, for instance, that we set the pattern to left_stack (9), the speed select to six, and the polarity to one, we would see 10011011 (0x9B):

```
PORTB = 10011011 (0x9B)

bit #    76543210
PORTB = 10011011 = 0x9B
POLARITYMASK = 00000001 = 0x01
-----
AND = 00000001 = 0x01

bit #    76543210
PORTB = 10011011 = 0x9B
SPEEDMASK = 00001110 = 0x0E
-----
AND = 00001010 = 0x0A

bit #    76543210
PORTB = 10011011 = 0x9B
PATTERNMASK = 11110000 = 0xF0
-----
AND = 10010000 = 0x90
```

To get the parameters using raw C, we would write:

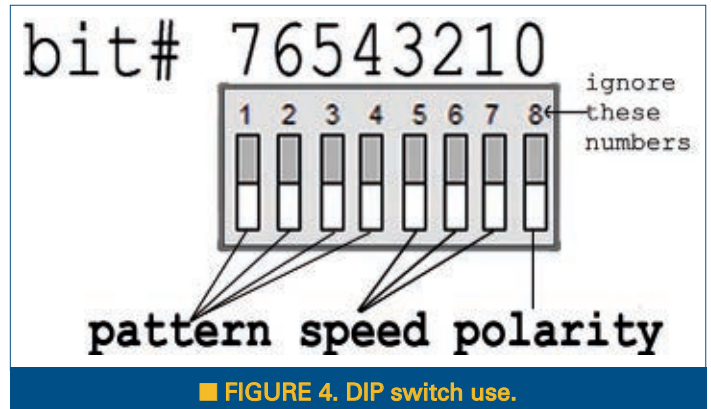
```
uint8_t pattern = 0;
uint8_t speed = 0;
uint8_t polarity = 0;
uint8_t dip_value = 0;

dip_value = get_dip();

// Using raw C bitwise operators
pattern = ((dip_value & PATTERNMASK) >> 4 );
speed = ((dip_value & SPEEDMASK) >> 1 );
polarity = dip_value & POLARITYMASK;
```

The only problem is that we have to remember where the field was in the mask so that we can remember to shift it the correct number of times. Or, we can give ourselves yet another bitwise crutch and write macros to get these parameters automatically so that we don't need to remember so much. This crutch would let us retrieve the pattern, speed, and polarity without having to remember anything about the size and position of our bit fields:

```
// Using a function as a crutch
pattern = get_mask_field8(dip_value, PATTERNMASK);
speed = get_mask_field8(dip_value, SPEEDMASK);
polarity = get_mask_field8(dip_value,
    POLARITYMASK);
```



■ FIGURE 4. DIP switch use.

As is often the case, I owe a debt to the folks at www.avrfreaks.net for the macros we'll use. I posted my concept and immediately was given a better way: www.avrfreaks.net/index.php?name=PNphpBB2&file=viwtopic&p=877894#877894 (Michael Hennebry provided the algorithm, and I changed the macro names to conform to my process):

```
#define bit_to_shift8(mask) ( \
    ((mask) & 0x01) ? 0 : ( \
    ((mask) & 0x02) ? 1 : ( \
    ((mask) & 0x04) ? 2 : ( \
    ((mask) & 0x08) ? 3 : ( \
    ((mask) & 0x10) ? 4 : ( \
    ((mask) & 0x20) ? 5 : ( \
    ((mask) & 0x40) ? 6 : 7 )))))))

#define get_mask_field8(byte, mask) \
    (((byte) & (mask))>>bit_to_shift8(mask))
```

This method allows the compiler to do some serious optimizing and according to another AVRFreak, Cliff Lawson, this wonder uses only four opcodes on an AVR!

If there is a down side, it is that this may well be one of the most complicated looking things we have seen so far. But if you'll take some time with it, you should be able to follow what it is doing. First, the bit_to_shift8 macro finds the number of 0 bits to the right of a mask. For instance, for our PATTERNMASK 0xF0 // 0b11110000 we see that after we mask the DIP switch we need to shift the value four places to the right to get the numeric value of the pattern field. As you remember from algebra, when you work a problem with parenthesis you evaluate the innermost one first, then sequentially each next inner parenthesis until you get to the final outer parenthesis.

In the case of the bit_to_shif8 macro, the system first evaluates the expression: ((mask) & 0x40) ? 6 : 7). This looks at the second highest bit position and if it is 1, then the lowest bit found — so far — is the 0x40 bit, number 6; if not, then it is 7. Next, it looks at ((mask) & 0x20) ? 5 : (X). This looks at the third highest bit position and if it is 1, then the lowest bit found — so far — is the 0x20 bit, number 5; if not, then it is what we found in the previous evaluation (either bit 6 or 7). The next



■ FIGURE 5. Next month's LCD navigator.

$((\text{mask}) \& 0x10) ? 4 : (\ \backslash)$ does exactly the same as before and determines the lowest bit so far. This continues until each bit has been evaluated.

For the PATTERNMASK, the lowest bit is 0x01 and the shift is 4. For the SPEEDMASK, the lowest bit is 0x02 and the shift is 1. For the POLARITYMASK, the lowest bit is the lowest bit 0, so the shift is also 0. So for our pattern mask, the bit_to_shift8 tells us how many bits to shift right. We just AND '&' our DIP switch value with our PATTERNMASK and shift it the four bits to get the number for the pattern.

I hope this is clear because if you understand it, you are getting fairly sophisticated in your understanding of C programming and bitwise operations. I also recommend rereading this section each night at bedtime if you have trouble falling to sleep (with this, you should find yourself nodding right off).

Okay, I've slipped off the rails again and run out of time and space (fortunately, gravity is still working), so if you want to see how this is used in a real chaser light application, you can get the source code at <http://code.google.com/p/avrtoolbox/> in the sources under avr_applications\simple-chaser_lights.

Next month, we will finish our study of DIO by using it with an LCD navigator as shown in **Figure 5**. If you want to get a head start on that project, you can get the

hardware from *Nuts & Volts* and the LCD navigator application source code from the avrtoolbox repository.

Questions? Well, now we have a new option. *Nuts & Volts* is hosting forums for its writers and you can find mine at <http://forum.servo-magazine.com>. If you want a really quick response — especially to a question not directly related to an article — you can put on your biohazard suit and start a thread at www.avrfreaks.net. (Read this blog entry first to find out why you need the biohazard suit: <http://smiley-micros.com/blog/2011/01/24/using-an-internet-forum>.) **NV**

Theory is all well and good, but to really learn this stuff you have to get your hands on some tangible items that blink, whirr, and sometimes detonate. As a service for the readers of the Smiley's Workshop articles, we have simple and inexpensive projects kits available that can help you make it real. You can find these kits (and some darn good books) at the *Nuts & Volts* Webstore.

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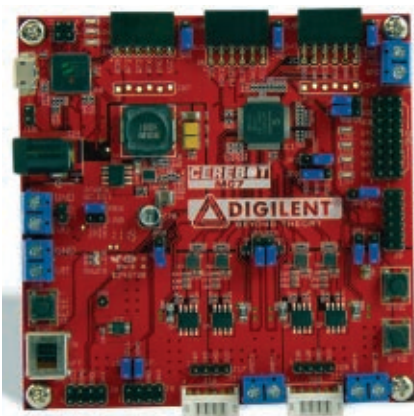
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motor connectors, the ability to use Digilent Pmod™ peripheral modules, and an integrated programming/debugging circuit that is compatible with the free MPLABIDE. Example applications include university embedded-systems and communications classes, senior capstone projects, and numerous other academic and hobbyist projects.

The Cerebot MC7 board features four half-bridge circuits that are rated

for 24V at up to 5A. These half bridges can be used to control two brushed DC motors, two bi-polar stepper motors, one brushless DC motor, and one uni-polar stepper motor. An onboard 5V, 4A switching regulator with an input voltage up to 24V simplifies operation of the board, enabling it to operate from a single power supply in embedded applications such as robotics. The onboard dsPIC33 DSC features 128 KB internal Flash program memory and 16 KB internal SRAM, as well as numerous on-chip peripherals, including an advanced eight-channel motor-control PWM unit, an enhanced CAN controller, two Serial Peripheral Interfaces (SPIs), timer/counters, serial-interface controllers, an Analog-to-Digital Converter (ADC), and more. The Cerebot MC7 board combines two pushbuttons and four LEDs for user I/O, as well as connections for two I²C busses — one of which contains an integrated serial EEPROM device. “The Cerebot MC7 board is an

ideal embedded motor control and general-purpose microcontroller experimentation platform for academics and hobbyists,” stated Clint Cole, president of Digilent, Inc.

The Cerebot MC7 development kit is available for \$119. It can be purchased from Digilent or from microchipDIRECT.

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Continued from Page 75

allow users to create complex, extremely rigid structures with ease using standard Hitec servos. The 1/2" aluminum hub shaft provides multiple mounting options using 6-32 screws. The robust 6061 T-6 aluminum



framework acts as a servo exoskeleton, enhancing the mechanical loads the servo can withstand. ServoCity's new .770" hub pattern is repeated throughout the framework to allow endless attachment options. ServoBlocks are



compatible with all standard size Hitec servos.

The kit comes unassembled; servo not included. The five piece kit is \$24.99.

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are designed for use with standard size Hitec and Futaba servos. A single servo mounting kit is \$6.99.

POLOLU M3PI ROBOT

Pololu announces the release of the m3pi robot — a high-performance, expandable mobile platform for use with ARM's powerful mbed development board. When socketed in the m3pi, the 32-bit mbed makes an extremely capable high-level robot controller that can be easily interfaced with wireless serial modules, additional sensors, and custom electronics.

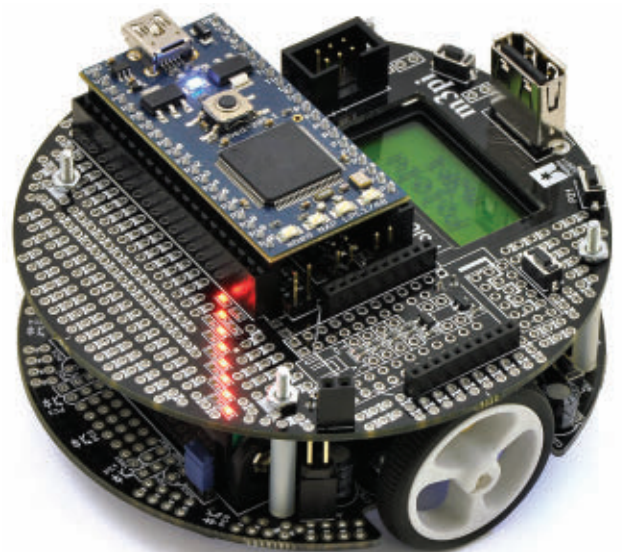
The m3pi robot consists of a 3pi robot base connected to an m3pi expansion board which includes sockets for an mbed development board and Wixel, or XBee wireless serial modules. The base ships pre-programmed with a serial slave program, so any microcontroller board capable of sending serial commands can be used as the m3pi's high level controller. Or, the 3pi base can be programmed directly. Since the heart of the m3pi is a 3pi robot, the m3pi has all the features of the 3pi robot, including a maximum speed of around 1 m/s,

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regulated motor power that prevents battery voltage from affecting performance, five reflectance sensors for line following and maze solving, an 8x2 character LCD, and a piezo buzzer for simple sounds and music.

A fully assembled m3pi robot with 3pi base included, is available for \$149.95. An m3pi expansion kit, which can be used to convert a 3pi robot into an m3pi robot, is available for \$27.95. An mbed module is not included.

For more information, contact:
Pololu Corp.
Web: www.pololu.com



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>>> QUESTIONS

Speed Control of a 3/4 HP 12 VDC motor

I would like to control the speed of a 3/4 HP 12 VDC motor with a 3.3 VDC microcontroller. I've seen in past issues where PWM was used to control small DC motors but not fractional HP motors.

Can someone show a circuit to interface the high power motor with a low power MCU from a 12V auto battery? Presently, I'm trying to use a Freescale MC9S08QG8 MCU. Ultimately, I would like to use the motor as a brake, and then reverse rotation on a small flywheel for a few revolutions.

The motor goes the same direction all the time, just the flywheel will reverse direction.

#12111

**Rod
Scotts, MI**

Pump Shut-off Needed

There is an electric pump on our boat that moves diesel fuel from one of four main fuel tanks to a day tank to run the engine. It can sometimes take up to 20 minutes to fill the day tank. Sometimes, we forget the toggle switch is on and the tank overflows through the vent line onto the deck. I need to devise a way to automatically turn off the pump when the tank is full, or at least after a specified interval of 5 to 10 minutes. There is no access for a float switch in the tank. Maybe some sort of timer circuit?

#12112

**LL
Long Beach, CA**

Schematics Needed

Conar Model 251 Oscilloscope

I need a schematic or manual for the Conar model 251 oscilloscope which Conar, I understand, was bought out by NRI/National Radio Institute/McGraw Hill. This is an old single channel 10 MHz analog scope. I need the manual to repair the scope.

I already know the power supply works and the cathode ray tube works since I see a momentary dot when the scope is turned off. I am on limited income but will be willing to pay for a copy of the schematic or manual for this scope.

#12113

**James C. New
Jacksonville, FL**

Stanley Garage Door Opener

Where can I get a schematic for the circuit board in my Stanley model 520 garage door opener? The circuit board has a burnt capacitor and I need to find the value to repair it.

#12114

**Orlando Silveira
Toronto, Ontario**

Microcontroller Cards

I'm just getting started with microcontroller cards. What is the difference between an AVR microcontroller card and a PIC microcontroller card? I am interested in purchasing a course kit that includes the books and the microcontroller card for the course.

#12115

**Steve Huff
Des Moines, IA**

>>> ANSWERS

[#11111 - October 2011]

Single-Stroke AC Bell

We would like to operate a single-stroke AC bell that would ring once every time the phone rings in cadence. The telephone line power – 40 to 120 VAC at 15 to 60 Hz – should power the bell. We prefer no external power supply. A typical single-stroke bell has a coil voltage of 24 VAC drawing 0.5

amps. Coil resistance is 10 ohms.

#1 First, let's correct the phone company specs. The IDLE line voltage is 48 volts; busy voltage is six to 12 (depends on the device). Ringing is zero volts to 60-100 volts (depends on the distance from the central office) at 20 Hz DC pulses.

The bell you intend to use requires 500 mA, but the phone company sends DC pulses AND is current limited to a few less than 10 mA. Any current draw over the limit is construed as an ANSWER, and stops ringing.

Your best bet is an AC input optoisolator such as the H11AA1 with a 0.1, 100V disc on one input and a 100K, 1/4W resistor on the other input. Connect the other ends of the resistor and capacitor to the phone line. The capacitor allows the AC component of the DC pulses to pass through while the resistor limits current through the opto LEDs. This opto has an open collector output which can be connected to a relay driver to ring the bell. External power is required.

Be aware the open collector will pulse low at 20 Hz, so some signal conditioning will be needed to get a solid low during the full one second ring cycle. If you want a diagram, email me at dhewett@phoneline.kscoxmail.com and I will send a typical circuit.

**Dennis Hewett
Frontenac, KS**

#2 I recommend that you abandon this device as it cannot be used directly on a phone line. Use a Wheelock

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!

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Check at www.nutsvolts.com for tips and info on submitting to the forum.

WHWR-AT-1-W or a WH-UTA-1. Both are electronic chimes that can be driven directly from the ring voltage on a phone line. Suppliers such as Graybar Electric, Teledynamics (www.teledynamics.com), or Target Distribution (www.targetd.com) carry it, as well.

**Chris Snyder
Cosby, TN**

[#11113 - November 2011] Frequency Changes In Cold Weather

I built the "Mail Delivered Detector" published in the June '06 issue of N&V (<http://nutsvolts.texterity.com/nutsvolts/200606/#pg44>) and was quite satisfied with the results. However, I found that the device stopped working in the cold weather. Adjusting the 25K pot on the receiver's 567 tone detector restored operation until the temperature changed and the device stopped working again. As an example, I measured the frequency of the transmitter's 555 timer at 68 degrees F to be 320 Hz, and at 20 degrees F it was 280 Hz. Can someone suggest any modification which will keep the 555 timer circuit in the transmitter on frequency as temperature varies between minus 10 degrees and 95 F, or a way to broaden the frequency range of the tone detector in the receiver?

#1 You can try to change your .22 μ F caps in the 555 circuit to low tolerance devices. Mouser part number 140-PEI2A224G-RC is a polyester unit with 3% tolerance from -40C to +85C. At the receiver, you can widen the bandwidth of the 567 by changing the capacitor at pin 2. National Semiconductor still hosts the spec sheet with the calculations at www.national.com/ds/LM/LM567.pdf.

**Alan
via email**

#2 The Parts List in the article that described your 555 circuit used a commercial temperature range, bipo-

lar-style 555 chip with carbon film resistors, and the 0.22 μ F capacitors were polyester-film types. If you used the same component types, I think your 555 circuit's poor performance with dropping temperature is likely due to those choices of components for the critical timing components; that is, the 555 IC itself, the timing resistor R17, and the timing cap C8 (the other circuit components will not be as severely affected). Commercial temp ICs are not intended for use below freezing – where your problems are occurring – so the 555 may be out of spec. You should use an industrial temperature range IC for the 555. Secondly, you probably should switch from a bipolar-style 555 to a CMOS-style 555 for your purposes, as the frequency of a CMOS-version 555 oscillator will be less affected by drops in battery voltage, and CMOS 555s enable the use of higher-value timing resistors. Thru-hole versions of CMOS 555 chips come from a variety of manufacturers. Their industrial temperature versions will have part numbers such as TLC555IP, TS555IN, ICM7555IP, LMC555CN, etc. The timing capacitor C8 is 0.22 μ F in the article, and if you used the polyester (mylar) cap indicated, the tempco of polyester caps is the poorest for the plastic film caps, thus giving the largest change in frequency with temperature in an oscillator circuit. It would be better to change a polyester cap to a polystyrene or polypropylene type, if you wish to use a film cap. You could also swap the C8 timing cap for a COG/NPO dielectric-type ceramic cap instead, as those types of ceramic caps also have very low tempcos (other types of ceramic dielectrics are unsuitable, however). Such higher performance caps are costlier and bulkier than polyester caps of the same capacitance value. For this reason, if you switch to one of those other types, you would benefit from using the CMOS-style 555 chip, since

the value of timing resistor R17 could be raised, so that a smaller value (and cheaper) timing cap C8 can be used. For example, you could use an R17 of 22K value in conjunction with a 0.1 μ F film cap for C8, or an R17 of 220K value in conjunction with a 0.01 mF COG ceramic cap for C8. Each of these combinations would provide the same RC timing period as in the original circuit. Finally, whatever value timing resistor you use, changing the carbon-film type R17 to a metal-film type resistor should improve its temperature performance, as well. Some carbon-film type resistors can have an order-of-magnitude worse tempco than good metal-film types of the same resistor value. In checking the website of parts supplier Mouser Electronics, I found suitable components in stock (CMOS industrial temperature range 555 ICs, 0.01 μ F COG ceramic caps, 0.1 μ F polypropylene film caps, metal film resistors); doubtless, other suppliers (Digi-Key, etc.) have them as well.

**William Braell
via email**

[#11118 - November 2011] Long Range Wireless RS-232

How can a long range wireless RS-232 link between two computers be built? I'd be very interested in how to get an effective range of 3-5 miles.

#1 Check out B&B electronics at www.bb-elec.com/product_multi_family.asp?multifamilyid=78.

**Chris Snyder
Cosby, TN**

#2 I'm curious ... why RS-232? RS-232 is a standard that describes the electrical, timing, and signal definitions for the transport of serial data. It does not define the pin assignments of the D-subminiature connectors commonly used for serial port connections on a computer. A few questions need to be addressed

before this question can be answered.

What data rate (throughput) is required? The maximum data rate usually found with a computer serial port is 115 Kbit or 230 Kbit. Will this link be half or full duplex? What type of modulation scheme will be used?

The answers to these two questions will be used to determine the bandwidth required for the wireless link. What is the purpose of this link? Is this for experimentation with radio communications (the same thing as wireless communications) or is there a serious application being implemented? If the latter, I'd seriously consider using currently manufactured IEEE 803.xx wireless Ethernet modems and high gain directional antennas. Three to five miles might be achievable. I was playing with the former over 30 years ago. Thanks for bringing back memories of fun times in early computer experimentation. Check out some of the earlier *Circuit Cellar* articles published in *Byte Magazine*.

**Douglas Hall, CPBE
Vilas, NC**

Comments

When I saw my answer published in September, I realized that I had made a big mistake. I missed two very important words in the original question: "inversely proportional." So, my circuit may not be the solution that Mr. Prigge is looking for.

The circuit is a form of constant current source. One end of R, point A, is held at V_{Ref} while the other end is connected to V, so there is a constant voltage difference across a constant resistance, and thus a constant current through R which must also flow through Rx to generate a theoretically linear voltage response.

My inner math geek says that a linear equation takes the form of $Y = M X + B$, where M is the slope of the line — $(V_{Ref} - V)/R$ in this case (the current through R) — and B is the Y intercept (where the line crosses the Y axis): V_{Ref}, in this case, and so the formula also shows this solution to be linear.

That's the ideal theory, but what can go wrong? There are a lot of mysteries (to me) about op-amps and I'll

leave out a bunch to concentrate on just three things that apply to all op-amp circuits and may impact this one.

1) An op-amp REALLY works by subtracting its input voltages and multiplying by a large gain, from one to 10 million depending on the op-amp. Thus, the assumption that A equals V_{Ref} is only true when the output is zero, but because of the really large open-loop gain, they stay quite close to each other; most op-amp circuits ignore the difference.

2) When computing the voltage divider of R and Rx, I assumed a perfect situation. Alas, most op-amps have a thing called input-bias current. When you present a voltage on their input pins, a small current flows and it changes with the voltage, disrupting the voltage divider. If we assume a hobby level precision with R at 1%, then, if we make sure the current through R is several hundred times the bias current, we (probably) won't notice the error. This implies that there is a practical upper limit to the value of R, depending on the op-amp.

3) Op-amps have a limited amount of output current and so there is also a practical lower limit to the value of R, again depending on the op-amp.

So, now break out the simulator. I had to assume many things. A V_{Ref} of 10V, a voltage of 12V, a max Rx of 10K thus an R of 2K, and I used a 741 model as that was one of the few that my simulator had built-in. I used a DC simulation and swept Rx from 0 to 10K, graphing the output.

Sure enough, it looked correct, but the eye can be fooled. The best way to confirm the linearity is to think about making a small change to Rx and observing the change in output. With a linear equation, the output should change by the same amount no matter what Rx we started with. Math geek calls this the first derivative of the output with respect to the input, and it should equal M — the constant slope of the line (and the current through R).

Of course, it wasn't a constant horizontal line. I captured the minimum and maximum derivative values and subtracted them to get an idea of

how things changed overall. This came to roughly an 80 nA difference between high and low. And there I'm stuck. I have no way of deciding if that is good enough.

So now, on to Mr. Cicchinelli's circuit where I start climbing out on a limb over a pool of quicksand. Using the voltage comparator to shut off the output when out of range was a cool idea, but as my simulator gets really slow with complex models I only addressed the U1.1 part.

It seems to me that it is based on a voltage subtraction circuit where we are subtracting 10V (the input to R1) from the voltage at the junction of R4, R5, and Rx (let's call that P). Thus, the output of the op-amp is always lower than P and so voltages are always negative. One of several ways this can be fixed is by supplying a negative voltage at R1 with a bi-polar supply.

Again off to the simulator, but I needed more information. I don't have the Applications handbook from National but I did find Application Note 31 by National on the web, and it had a circuit that looked like this one. It used 2M for R1 and R2, and 1M for R3 and R4, and 2K for R5. With these values in place and -1V at R1 to keep from clipping (plus a formula to map the output to the proper range), I ran the simulation. The bottom line is that the change in slope (current) from min to max was around 6 μ A. It sounds good but again, I have no idea if it is good enough.

**Jim Brannan
Santa Clara, CA**

Reprinted from September
Resistance Amplifier

I was wondering if someone knows how to design a circuit to measure resistance. I would like to jumper select the input range, run it through a zero and span circuit, and output a 0-10 VDC signal inversly proportional to the selected resistance range.

As the resistance goes down to the bottom of the range, the output would increase to the maximum (10 volts). As the resistance increases to the maximum of the range, the voltage on

the output would go down to zero. As with all analog designs, linearity is important. I have seen circuit boards that do this. They have two eight-pin chips on them, two trimmers, and a small assortment of misc. parts. Simple is good.

Producing a suitable power supply for this circuit is the easy part, so I can come up with that on my own.

Consider the non-inverting voltage amplifier of **Figure 1**. Normally, we construct it with V connected to ground, but we don't have to. To compute the voltage at A for any output, observe that the voltage A-V is across R while the voltage Out-V is across X+R, and the currents are the same through both resistors, so:

$$\frac{A - V}{R} = \frac{Out - V}{X + R}$$

Skipping all of the tedious algebra while solving for Out – and realizing that it is an op-amp's job to keep its two inputs equal by changing its output –

thus $A = V_{Ref}$. We get:

$$Out = (V_{Ref} - V) \times \frac{X}{R} + V_{Ref}$$

So, if you want the output to be 10V when X is zero, V_{Ref} must be 10V. Skipping more algebra while solving for the ratio of X to R when Out is zero, we get:

$$N = \frac{X}{R} = \frac{V_{Ref}}{V - V_{Ref}}$$

So, with $V = 12V$ and $V_{Ref} = 10V$, the multiplier N is 5, i.e., the output is zero when X is five times R. Alternately, a V of 11V gets a multiplier, N, of 10. Though some op-amps are rail-to-rail, they still have difficulty getting all the way there. It's best to use a bi-polar supply with enough head space to let the op-amp be comfortable and stay linear. Since no negative voltages are used, the negative supply only needs to be low enough to give clearance and can be any voltage lower than about -1.5V. You may want to use a second op-amp from a dual package as an output buffer (voltage follower), depending on the intended load. You can change

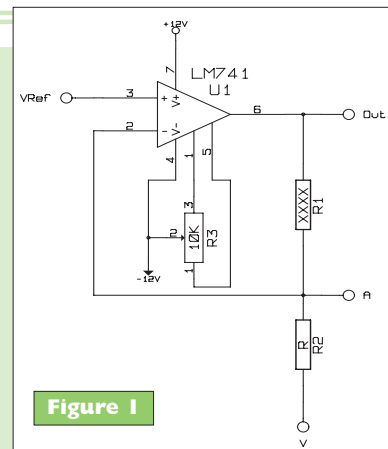


Figure 1

V or R or both to change the range. Changing V_{Ref} changes both the span and the range. Use the offset adjust (R3) to make the output 10V when X is zero. Since there are tens of thousands of op-amps to choose from, it is probably best to look to your favorite store, see what they have, and consult the spec sheets. For increased accuracy, you could choose an instrumentation op-amp. The bandwidth is probably irrelevant depending on just what the resistance source is and how fast it changes.

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Programmable DC Electronic Load 0~80V / 0~40A



The 3721A Programmable DC Electronic Load provides excellent performance with sophisticated features found on much more expensive units. This 400 watt, 40 Amp, 0~80 volt Programmable DC Electric Load can be used to test all sorts of DC power sources including power supplies and is especially helpful to battery manufacturing processes. This DC load features constant voltage, constant resistance, constant current and constant power settings. The end user can design programs that control precisely all of the load values and time durations for each step of a test sequence. Up to nine 10 step programs can be internally stored in the 3721A Programmable DC Load.

4 basic functions: CC, CV, CR & CP

8 basic test modes: CCL, CCH, CV, CRL, CRM, CRH, CPV & CPC

Minimum operating voltage is less than 0.6v at the load's full rated current.

High-speed sequence, high-speed transient, short circuit, battery discharge and other functions.

Programable current slew rate.

Multiple groups of parameters and lists can be saved & recalled.

Supports SCPI and LabView with included software.

Current Rating: 0~40A

Voltage Rating: 0~80V

Power Rating: 400W at 40°C

Item#
CSI3721A

\$720.00

www.CircuitSpecialists.com/CSI3721A

Programmable DC Electronic Loads



These 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

Your Hot Air Rework Headquarters

Surface-Mount components have taken over from through-hole components in many electronic products produced today. Circuit Specialists, Inc stocks numerous Hot Air Rework solutions to handle this trend.

Our many rework solutions offer a wide range of nozzle designs and many have built-in holders for efficient placement of the air stream for proper application of heat/airflow over the desired component.

www.circuitspecialists.com/hot-air-rework



BlackJack SolderWerks
Hot Air System
with Suction Pen
& Mechanical Arm.

BK4050
\$119.00

www.circuitspecialists.com/bk4050



BlackJack SolderWerks
Hot Air Rework Station
with Digital Display, Mechanical
Arm & 70w Soldering Iron.

BK5050
\$169.00

www.circuitspecialists.com/bk5050



BlackJack SolderWerks
Deluxe Rework System with
Hot Air, Soldering Iron, Suction
Gun & Mechanical Arm.

BK6000
\$229.00

www.circuitspecialists.com/bk6000



CircuitSpecialists.com
Compact Rework Center with
Hot Air Gun and Soldering Iron.

CSI899A+
\$99.00

www.circuitspecialists.com/csi899a+



CircuitSpecialists.com
ESD Safe, CPU Controlled,
SMD Hot Air Rework Station
with Hot Air Gun & Suction.

CSI825A
\$99.00

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ESD Safe SMD Rework Station
with Hot Air Gun
& Soldering Iron.

CSI906
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www.circuitspecialists.com/csi906



CircuitSpecialists.com
Hot Air Gun w/Digital Display for
Surface Mount Devices.

CSIHOTGUN-2
\$89.00

www.circuitspecialists.com/csihotgun-2



CircuitSpecialists carries a large
selection of Nozzles for BGC,
PLCC, QFP, SOP and single
point applications.

www.circuitspecialists.com/hot-air-nozzles

60 Watt Digital Soldering Station

For use with traditional or Lead Free Soldering



Features:

- * 60 watt dual core ceramic heater
- * 150 to 450 degree Celsius Temperature range
- * Versatile easy to read liquid crystal display
- * 3 preset & user definable temperature settings.
- * Automatically remembers previous temperature setting
- * Display in Celsius or Fahrenheit scale
- * 3 foot cord length from station to iron tip
- * Broad selection of replacement tips available



Item#
CSI-Station-3DLF **\$49.00**

www.CircuitSpecialists.com/CSI-Station-3DLF

Circuit Specialists carries a wide selection of traditional & lead-free soldering equipment, including soldering irons, soldering stations, hot-air rework stations, focused infrared systems, reflow ovens, pre-heating systems, regular and lead-free solder, solder flux, and soldering aids for both thru-hole and surface-mount soldering.

See our complete line of soldering equipment at:

www.CircuitSpecialists.com/soldering-equipment





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

Best Value, Low Cost Station 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 separate 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

3 Channel Programmable Regulated DC Power Supplies



Check out our new programmable hi performance 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.

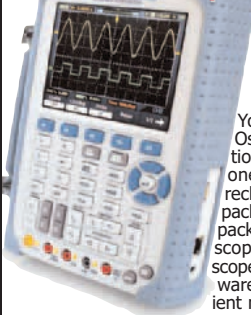
CSIPPS33T 0~32V / 0~3A **\$299.00**

www.CircuitSpecialists.com/CSIPPS33T

CSIPPS55T 0~32V / 0~5A **\$379.00**

www.CircuitSpecialists.com/CSIPPS55T

200MHz Hand Held Scopemeter with Oscilloscope & DMM Functions



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 leads, 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** New Low Price! **\$589.00**

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** New Low Price! **\$429.00**

www.circuitspecialists.com/DSO1060

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** New Low Price! **\$519.00**

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

www.CircuitSpecialists.com/inspection-cameras

Ideal for Law Enforcement,
Post Fire Inspection, Plumbing,
Facilities Maintenance,
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.

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 attachable 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 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!).

www.CircuitSpecialists.com/aardvark-ii

Item# **AARDVARK II** **\$199.00**



Aardvark Nine 9mm Wireless Inspection Camera With Color 3.5" LCD Recordable Monitor

Your Extended Eyes & Hands!

Same great Aardvark Wireless Inspection Camera System, but with only the 9mm Camera for a lower cost option!

Item# **AARDVARK NINE** **\$149.00**

www.CircuitSpecialists.com/aardvark-nine

Regular \$99.95 Aardvark Jr 9mm Wireless Inspection Camera With Color LCD Monitor



**INVENTORY
BLOWOUT
SALE**

With its small 9mm camera head, the Aardvark Jr allows for easy visual inspection in hard-to-reach areas. Lightweight, handheld design to easily find, diagnose and solve problems with the flexible extended tube and useful accessories.

Item# **AARDVARK JR** **\$49.95**

www.CircuitSpecialists.com/aardvark-jr



2011 Gift Guide



For all your holiday gift giving (and gift getting!) needs, here is a tailored group from our vast selection of microcontrollers, robots, kits, sensors and accessories. For complete product catalog, visit www.parallax.com (Clockwise from upper left)

Boe-Bot Robot Kit (USB Version; #28832; \$159.99) Learn programming and robotics with this BASIC Stamp-controlled robot kit. Serial with USB adapter version also available (#28132)

PING)) Ultrasonic Sensor (#28015; \$29.99) Easy method of distance measurement for robotics, security, and infrared replacement applications.

S2 (Scribbler 2) Robot (#28136; \$129.99) The S2 is pre-programmed with 8 demo modes and has a colorful GUI programming interface for your PC.

VPN1513 GPS Receiver module (#28506; \$59.99) An open source, customizable GPS solution that can track up to 20 satellites.

Memsic 2125 Dual-axis Accelerometer (#28017; \$29.99) A dual-axis thermal accelerometer to measure tilt, acceleration, rotation, and vibration; range of ± 3 g.

BASIC Stamp Activity Kit (#90005; \$79.99) Learn circuit-building and programming at the same time with the BASIC Stamp microcontroller!

PIR Sensor (#555-28027; \$10.99) A passive infrared motion sensor for your microcontroller project.

RFID Reader and Tag Sampler Kit (Serial; #32390; \$42.99) Easily read passive RFID transponder tags.

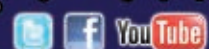
Order online anytime at www.parallax.com or call toll-free at 888-512-1024 (M-F, 7AM-5PM, PDT).

Friendly microcontrollers, legendary resources.™

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