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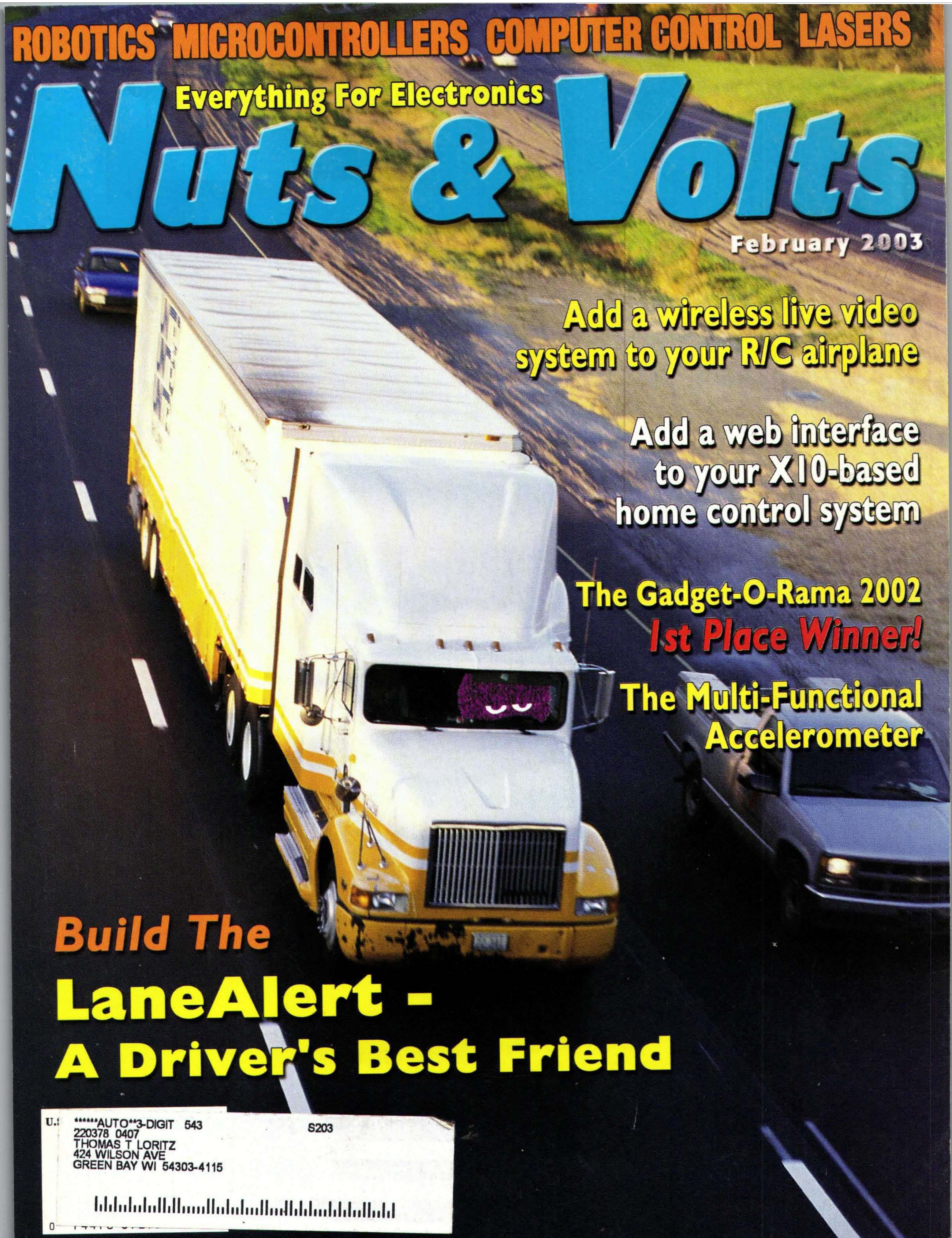
Nuts & Volts

February 2003



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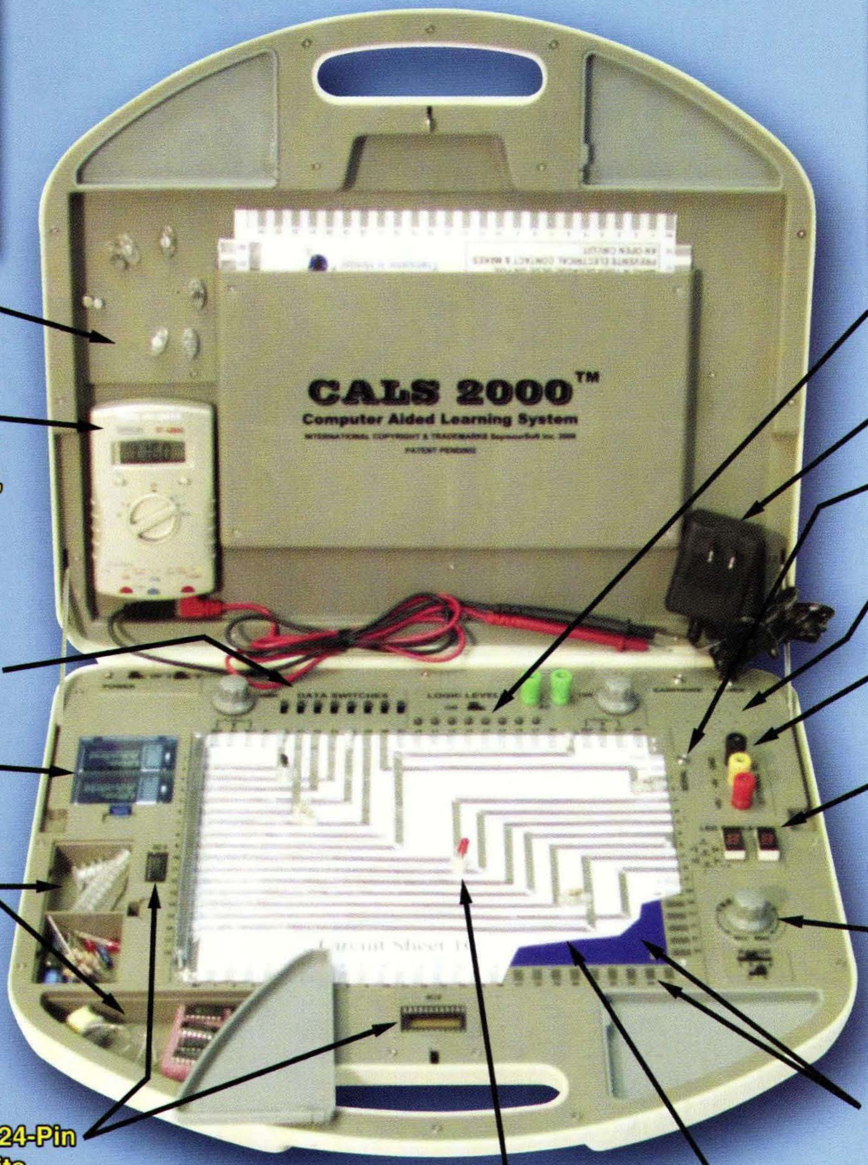

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Nuts & Volts

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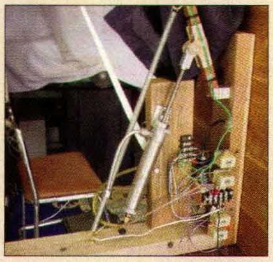
Reader Feedback

Dear Nuts & Volts:

I just completed the Martha Project. Everything went per your instructions or as I interpreted them. I made some substitutions and added some things.



The really hard part was getting the sounds to work to my satisfaction. I thought that I had a tape player that would stop and start with the closing of a switch, no luck there. I am going to leave the continuous tape running with the scream going and turn on the sound with a relay. I am using a set of computer speakers with amplifiers. I have four relays: one drives the LEDs for the eyes, one turns on the black light, and one for the sound. That leaves one for something I may have forgotten. This project has been fun, I may do the seagull later.

Don
via Internet

Dear Nuts & Volts:

I liked your article on building a Jacob's Ladder in the Dec. '02 issue.

However, there is one glaring omission in the circuit: A bypass capacitor across the 12-volt supply. All electronic circuits should be properly bypassed to prevent interaction between sections of the circuit. In this application, the requirement for a capacitor is much more severe, since the AA battery supply is required to supply perhaps six amperes of pulse current into the ignition coil primary, which may be only two ohms. The only way to get a decent current into the coil is through a charged capacitor. For a typical three-millisecond pulse width, the value of the capacitor should be at least 3,000 microfarads.

Joe Dean, via Internet

Dear Nuts & Volts:

Your magazine is *great*. That is why I'm not only renewing *my* subscription, I'm giving the gift sub to my friend. Keep up the good work. I would like to see a little more OOPIC.

Edward Carty, Jr., via Internet

Dear Nuts & Volts:

Kudos, dittos, and all that stuff ... we really like your new format! It's finer than frog hair!

Vern Killion W5UYF
DOE KRVN/NRRA/NE State SECC-EAS

Dear Nuts & Volts:

Neat magazine, greatly enhanced by the new size. It was difficult to take the larger format on trips. Fitting it into a briefcase or on a bookshelf was also a problem. Thank you.

Robert Mitchell, via Internet

TechKnowledgey 2003

Events, Advances, and News From The Electronics World

Advanced Technologies

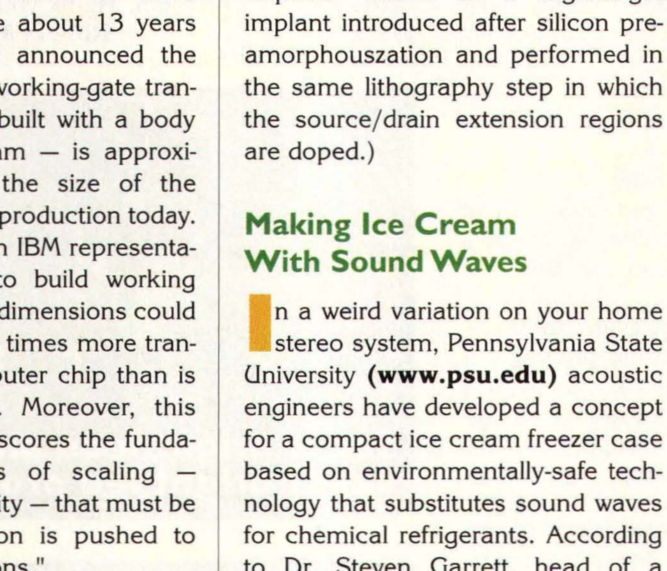
New World's Smallest Transistor

In 2001, the Consortium of International Semiconductor Companies projected that transistor dimensions will need to shrink to less than 9 nm by 2016 or current performance trends in digital equipment cannot be maintained. IBM **(www.ibm.com)** seems to have crossed that hurdle about 13 years early and recently announced the development of a working-gate transistor that can be built with a body length of only 6 nm — is approximately one-tenth the size of the smallest devices in production today.

According to an IBM representative, "The ability to build working transistors at these dimensions could allow us to put 100 times more transistors into a computer chip than is currently possible. Moreover, this achievement underscores the fundamental challenges of scaling — namely power density — that must be addressed as silicon is pushed to molecular dimensions."

For decades, the chip industry has been challenged by the limitations of scaling, especially because smaller transistors are more difficult to turn on and off. Reportedly, IBM has been able to solve the problem by reducing the silicon thickness on the silicon-on-insulator (SOI) wafers. The devices are produced on bonded SOI wafers using halo implants and 248-nm wavelength lithography. The silicon body of the device is only 4 to 8 nm thick, which results in proper turn-on and turn-off behavior. (In case you are wondering, "halo implant" refers to a high-angle implant introduced after silicon preamorphouszation and performed in the same lithography step in which the source/drain extension regions are doped.)

Illustration of IBM's "world's smallest transistor." Courtesy of International Business Machines Corporation. Unauthorized use not permitted.



RSD stands for "Raised Source Drain"

Making Ice Cream With Sound Waves

In a weird variation on your home stereo system, Pennsylvania State University **(www.psu.edu)** acoustic engineers have developed a concept for a compact ice cream freezer case based on environmentally-safe technology that substitutes sound waves for chemical refrigerants. According to Dr. Steven Garrett, head of a research team financed by Ben & Jerry's ice cream company, the team's thermoacoustic chiller uses a souped-up loudspeaker to generate high-amplitude sound energy in an environmentally-safe gas (air) that is converted directly into useful cooling. The high amplitude sound levels are hundreds of thousands of times beyond even rock concert levels — up to 173 dB.

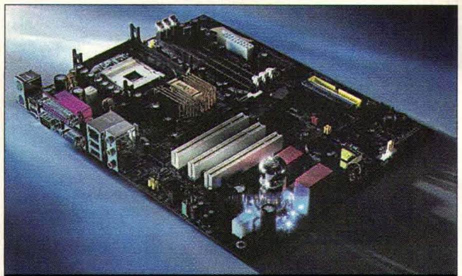
The loudspeakers used in thermoacoustics do not need to produce a range of frequencies or tones like a radio, so Garrett's group improves their efficiency by operating them at resonance or at the tones they produce by the natural free oscillation of the system. The Penn State group has developed loudspeakers that not only operate near their natural resonance frequencies, but also use metal bellows that replace loudspeaker cones to compress the air.

In a proof-of-concept test system, the process was used to cool a piece of window screen. Reportedly, the test equipment pushed the screen down to -8°F (-22°C). Garrett commented, "What began as basic research on the fundamental connections between sound waves and heat transport — funded by the Office of Naval Research — is getting closer to providing an environmentally-benign substitute for traditional engine and refrigeration technology."

Computers and Networking

Audio Card Provides Tube Sound

If you are a musician or a passionate audiophile, you undoubtedly understand that digital electronics simply cannot provide the warm,



AOpen's AX4GE/PE sound cards provide old-fashioned tube audio from your PC. Courtesy of AOpen, Inc.

fuzzy tones that you get with vacuum tubes. If you overdrive the input of a transistor, it disappears in a puff of smoke. If you overdrive the input of a vacuum tube, you get a wonderfully rich distortion. This is why electric guitar players still love their 40-year-old Fender Twin Reverb amps and many music lovers cling to their noisy old tube amplifiers. Apparently, it is now possible to get the same sound from your PC using one of the recently-introduced AOpen AX4GE/PE sound cards. The sound is created not by exotic digital processing, but by a real SOVTEK 6922 dual triode vacuum tube that operates as part of the amplification circuitry. The result is more pleasant sound for musical audio applications and more robust sound-effect reproduction for video games.

Several versions are available. Based on the Intel® 845PE chipset, the AX4PE model can be obtained with Serial ATA and Ultra ATA 133 hard drive interfaces. The AX4PE Tube-G version excludes these options. The AX4GE card, based on the 845GE chipset, adds Intel's "Extreme Graphics" core, which offers realistic 3-D graphics for gaming. All models support Intel's Hyper-Threading technology and Dolby Digital 5.1 surround sound. Reportedly, the street price runs from $180.00 to $220.00. To find a dealer in your location, log onto the AOpen web site at **www.aopen.com**.

Top 10 Viruses for 2002

The results have been tabulated, and the top 10 computer viruses of 2002 have been announced. According to Sophos, a UK-based developer of anti-virus software **(www.sophos.com)**, the Klez worm holds the dubious honor of being the world's most prolific virus, being the object of 24.1 percent of all complaints recorded by the company's customer-service department.

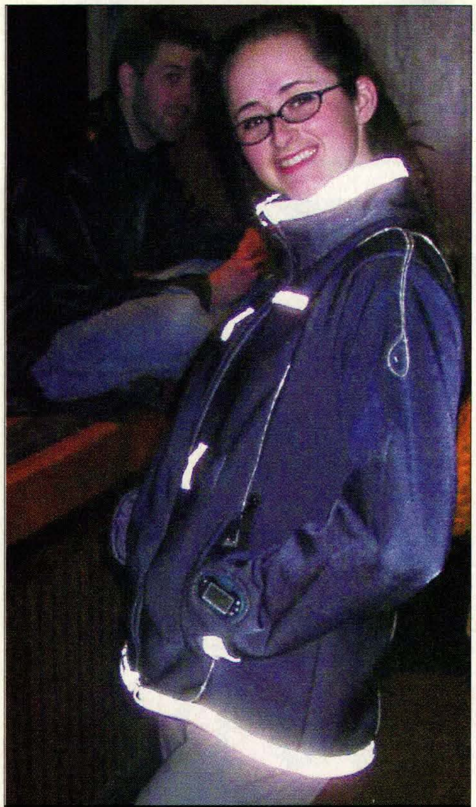
Transmitted via email, it substitutes an incorrect (but real) return address for the address of the real sender, making it appear that the worm was sent by a third party. According to Sophos, "This has led to a flurry of accusations that innocent computer users have sent the worms to customers, suppliers, and colleagues. In some cases, Mac users have been blamed for sending the Klez worm, even though it is impossible for Macs to be infected. This has caused embarrassment to some managed email security companies that have been falsely accusing users of forwarding viral code." In fact, nine of the viruses in the 2002 top 10 are mass mailing Windows 32 viruses, the exception being the ElKern virus, which is carried by Klez. Approximately 87% of all infection reports during 2002 concerned Windows 32 viruses.

The number two and number three bugs in the top 10 list are Bugbear (17.5 percent) and Badtrans (14.6 percent). The remaining viruses logged less than five percent of the total complaints. In 2002, Sophos detected 7,189 new viruses, worms, and Trojan horses, bringing the total to more than 78,000. On average, the Sophos-virus labs produce detection routines for more than 25 new viruses every day.

Circuits and Devices

Clothing with a Brain

US-based clothing manufacturers are rapidly losing ground to low-cost Asian producers, but a ray of hope can be seen in the creation of Lucy Dunne, a graduate student at Cornell University **(www.cornell.edu)**. In the photo, (next page), she shows a jacket that automatically lights up in the dark and produces heat when the temperature drops. It also incorporates a pulse monitor to measure activity levels for people who jog or walk for exercise. Heat is



Lucy Dunne of Cornell University models the smart jacket she designed, which automatically heats and lights up in the cold and dark, and features a pulse monitor to measure activity level for recreational athletes. Photo credit: Komposite.

produced by an electroconductive cloth in the upper back section, and light emanates from electroluminescent wires attached at strategic locations. This prototype jacket is powered by AA cells, so it presumably isn't very effective at arctic temperatures. But a commercial version might use lithium batteries, or perhaps the wearer could drag around a wagon full of automotive batteries.

More importantly, this is but one example of a developing "smart clothing" market that employs microprocessors and other electronics for specific purposes. Products that may appear in your local department store soon include snow suits with embedded GPS receivers, shirts with integrated cell phones, bikinis with built-in audio players, and undershirts with various remote physiological monitoring devices. Perhaps, we can look forward to hats that convert into umbrellas when they sense rain, shoes that spray salt on icy surfaces, and pants that automatically fall down when you enter a crowded elevator. The possibilities for appearing ridiculous seem endless.

If you are seriously interested in the subject, you may want to attend the next IEEE International Symposium on Wearable Computers. (The sixth annual event was held last October in Seattle, WA.) Updated information is available at **iswc.tinmith.net/**. You can even have information about the conference emailed to you on a regular basis. Just send an email with the key words "subscribe iswc" in the body of the message to **majordomo@iswc.tinmith.net**.

Electronic Voice Changer

Tronic Ace Technology, Inc. **(www.unitone.com.tw)** is a manufacturer of security and novelty electronics ranging from talking alarm clocks and ultrasonic animal repellers to mobile phone accessories, which are sold under the Unitone brand name. One of the company's more interesting products is the Televoicer, which is used to disguise your voice when talking on the telephone. Several versions are available. For example, the LG-206A (left photo) is the portable version, and you just tape it to the mouthpiece of a telephone to allow it to operate. You can select from eight levels of voice modificaon. The LG-215A and LG-215B models are connected between the telephone body and handset, providing 8 and 16 different modification levels, respectively.

The Televoicer voice changer comes in several versions, including a mask. Courtesy of Tronic Ace Technology, Inc.

There is also the LG-510A, a miniaturized version designed for use with cell phones. But the most intriguing has to be the LG-301 (right photo), which is built into a rubber mask and requires no telephone at all. The manufacturer advises that it is highly useful during the Easter holidays, but offers no explanation of that concept. It does seem like a useful item if you plan to rob your local convenience store. A quick Internet search turned up several web sites offering the Televoicer at prices starting at about $29.00. Tronic Ace is also looking for distributors, so contact them right away if you think you can sell these products.

Industry and the Profession

IEEE Medal of Honor Winner

Nick Holonyak Jr. — a John Bardeen Professor of Electrical and Computer Engineering and Physics at the University of Illinois at Urbana-Champaign — has been selected as the 2003 recipient of the Institute of Electrical and Electronics Engineers (IEEE) Medal of Honor. The award, which recognizes Holonyak "for a career of pioneering contributions to semiconductors, including the growth of semiconductor alloys and heterojunctions, and to visible light-emitting diodes and injection lasers," will be presented at the IEEE's annual honors ceremony in June 2003.

The son of Slavic immigrants who settled in southern Illinois, Holonyak earned his bachelor's degree in 1950, his master's in 1951, and his doctorate in 1954, all in electrical engineering from the University of Illinois. Holonyak was the first graduate student of two-time Nobel laureate John Bardeen, an Illinois professor who participated in the invention of the transistor. An early researcher in semiconductor electronics, Holonyak gained eminence through his numerous inventions and contributions to advances in semiconductor materials and devices.

At the University of Illinois, Holonyak and his students demonstrated the first quantum-well laser, creating a practical laser for fiber-optic communications, compact disc players, medical diagnosis, surgery, ophthalmology and many other applications. In the early 1980s, his group introduced impurity-induced layer disordering, which converts layers of a semiconductor structure into an alloy that has important electronic properties. In one use, this discovery was used to improve a laser's reliability to make it applicable for use in DVD players and other optical storage equipment.

Among Holonyak's other awards are the Frederic Ives Medal of the Optical Society of America (2001), the Japan Prize (1995), the National Academy of Sciences' Award for the Industrial Application of Science (1993), the Optical Society's Charles Hard Townes Award (1992), and the US National Medal of Science (1990). He is a member of the National Academy of Engineering and of the National Academy of Sciences, and a fellow of the American Academy of Arts and Sciences, the American Physical Society, the IEEE, the Optical Society of America, and is a foreign member of the Russian Academy of Sciences. **NV**

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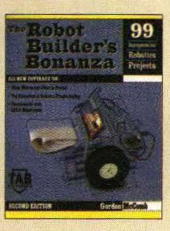

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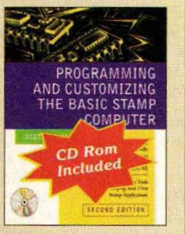

This edition moves you briskly from electronic foundations through BASIC Stamp "Boot Camps" and an intelligent traffic signal simulation to build a robotic bug with whisker sensors, a time/temperature display, and a data-logging thermometer. **$39.95**

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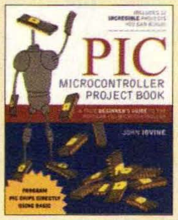

This project-oriented guide gives you 12 complete projects, including: using transistors to control DC and AC motors, DTMF phone number logger and distinct ring detector and router ... home automation using X-10 communications ... digital oscilloscope ... simulations of fuzzy logic and neural networks ... and many other applications. **$29.95**

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In 1995, Scott Edwards began authoring a column on BASIC Stamp projects in *Nuts & Volts Magazine*. The column quickly became a favorite of *Nuts & Volts* readers and continues today with Jon Williams at the helm. *The Nuts and Volts of BASIC Stamps* is a collection of about 75 of these columns.

Radio & RF

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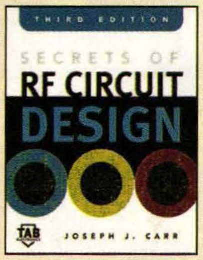
3rd Edition by Joe Carr



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Electronics

Encyclopedia of Electronic Circuits Vol. 7
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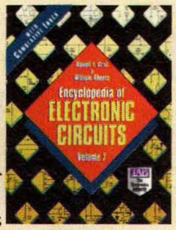

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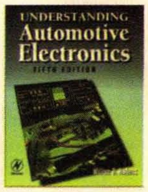

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Guide To Understanding Electricity & Electronics
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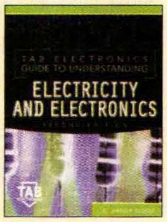

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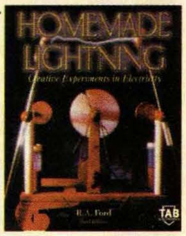

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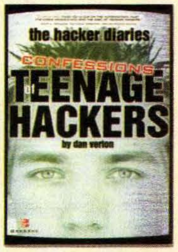

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Electronics Q&A

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, as well as comments and suggestions.

You can reach me at: **TJBYERS@aol.com**.

What's Up:

This month is audio/visual. Two audio test instruments and two ways to get stereo from mono. Two LED projects: colorimeter and auto taillights. And a new antique radio supplier category for the FINDPART file.

Audio Wattmeter Uses DMM

Q. I am in need of a direct-reading analog audio wattmeter capable of indicating RMS power up to 100 watts (or more) using a 4-, 8-, or 16-ohm dummy load. I have searched the Internet to no avail. Can you help?

John Pinto
Morgan Hill, CA

A. If you have a DMM (digital multimeter), you can calculate the power output of an audio amplifier. The RMS power rating of an audio amp is measured by applying a sinewave at the input of the amplifier and measuring the AC voltage at the output using the AC settings of the DMM. The power output can then be simply calculated from the equation:

$$\text{Power (RMS)} = \text{Volts}^2 \text{ (RMS)} / \text{Impedance}$$

For example, the wattage of an amplifier with an output of 20 volts across a four-ohm load is:

$$\text{Power} = 202 / 4 = 400 / 4 = 100 \text{ watts}$$

What is the wattage of 36 volts across an eight-ohm load? Rather than hauling out the calculator, I looked it up using the chart in Figure 1.

However, RMS amplifier power shouldn't be confused with the Peak Music Power (PMP) rating. PMP takes into account that music isn't a continuous sinewave, but contains sudden sharp peaks within the music content. At an output level where these sudden peaks just begin to distort, the underlying music level will be a mere percentage of this — typically 40%. That means the demand on the power supply will also only be 40% of its rated value. Most audio systems take this into account and specify their power output ratings in peak watts rather than RMS — that is, they are taking advantage of the average power of the power supply. An audio amplifier rated at 100 watts PMP will actually be about 70 watts peak, and

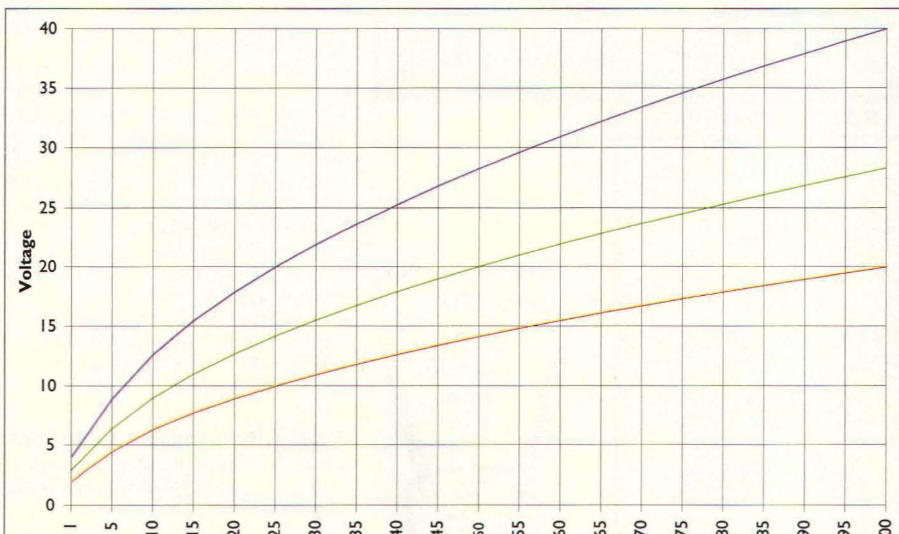


Figure 1

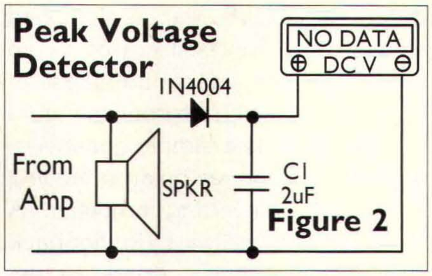


Figure 2

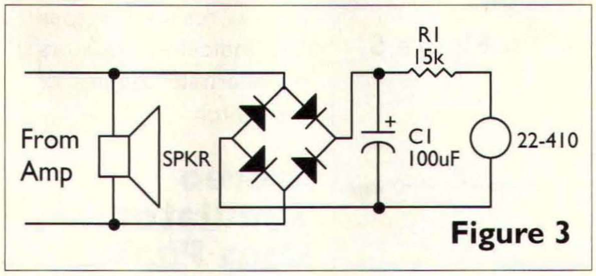


Figure 3

35 watts RMS.

For this, you need some way of measuring peak voltage using your DMM. Here's a simple circuit that will do just that (Figure 2). The response time of this circuit should be about one second (assuming you have a one-megohm DMM). This can be changed by decreasing (faster response) or increasing (slower response) the value of C1. You can use the same chart in Figure 1 for the calculations.

Still want an analog meter? No problem — except for the calibration of the scale. Simply replace the DMM with the circuit in Figure 3. I used a RadioShack 15-volt panel meter (22-410) for my experiments. Using the values shown, full scale will be 55 watts into a four-ohm load. You'll have to adjust the value of R1 for other speaker impedances. For 55 watts at 16 ohms, R1 is 30k. Use the chart in Figure 1 for the R1 calculations (hint: use Ohm's Law) and scale calibration. You'll probably want to flip the scale over and use a marker pen or decals to create a new meter face.

Audio Level Meter Uses LEDs

Q. I would like a circuit design that would indicate the peak voltage of an audio signal, and display it on a trio of LED bar-graph devices, like the Mouser 351-2403. It would be desirable to acquire the input signal directly from the speaker wires, but monitoring the output of the pre-amp output of my stereo receiver is acceptable. While the peak-hold feature is desirable, it isn't absolutely necessary.

Dale L. Smith
Lafayette, NJ

A. To begin with, you really don't need 30 LEDs — which equals 90dB — to measure most audio signals. To reduce circuit complexity (which is already complex enough for this column), I set the range to 60dB by reducing the number of LEDs from 30 to 20 (two bar display devices). The circuit (Figure 4) uses two LM3915s log dot/bar display drivers that are easily cascaded.

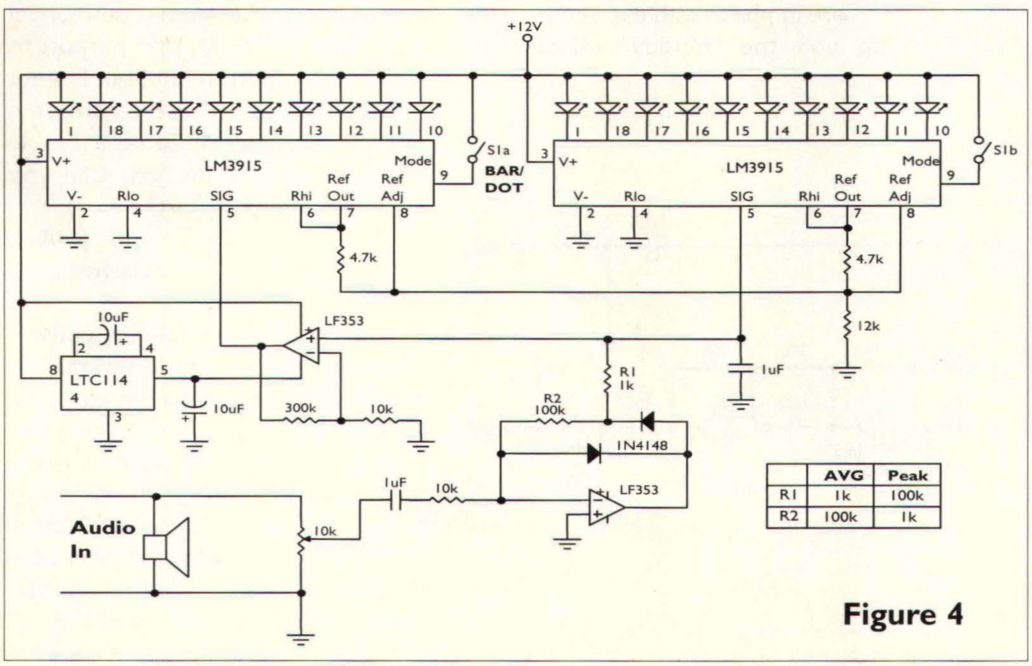


Figure 4

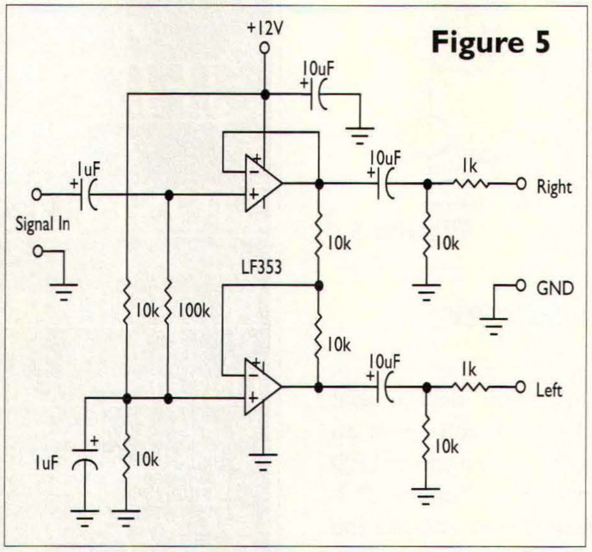


Figure 5

The display driver part of the circuit is the classic dot/bar display driver as outlined in the LM3915 datasheet. All that is needed is an interface to the speaker, which was also shown on the datasheet, but not in full detail. To make this circuit work, a split power supply is needed for the LM353 op-amp. To increase accuracy, I used an LTC114 voltage inverter. In this design, any change in the source voltage (V+) is automatically mirrored in the V- line so that the zero reference point won't drift.

You'll also notice that I've included resistance values for both peak and average measurements. If you wish to switch between them, simply use a DPDT switch to insert a parallel 1k resistor across the indicated resistors on alternate toggles of the switch.

Stereo Simulator Uses Phase Inverter

Q. I saw your solution to the "Speaker Mixer" question in the Dec. 2002 issue, and was reminded of a similar problem I have. My PC has a stereo capture card that I use for digitizing videos. The problem is that my analog camcorder is mono, so only one channel of the audio gets connected to the capture card. I've tried using a "Y-adapter" to share the audio signal on both the left and right channels, but the audio sounds like it's under water. Can you suggest a simple audio splitter circuit that would allow me to feed the audio signal from the camcorder to both the left and right channels of the capture card?

Kelly Small
Phoenix, AZ

A. The problem is that the signals are in phase with each other, giving you the "muddy" effect you describe. What you want is simulated stereo. The simplest form of stereo simulation is to reverse the phase of one channel, as I have done in Figure 5. The circuit is a simple non-inverting voltage follower op-amp feeding a unity-gain inverting amplifier. A small 12-volt wall-wart (RadioShack 273-1773 or equivalent) is all the power supply you need for this design.

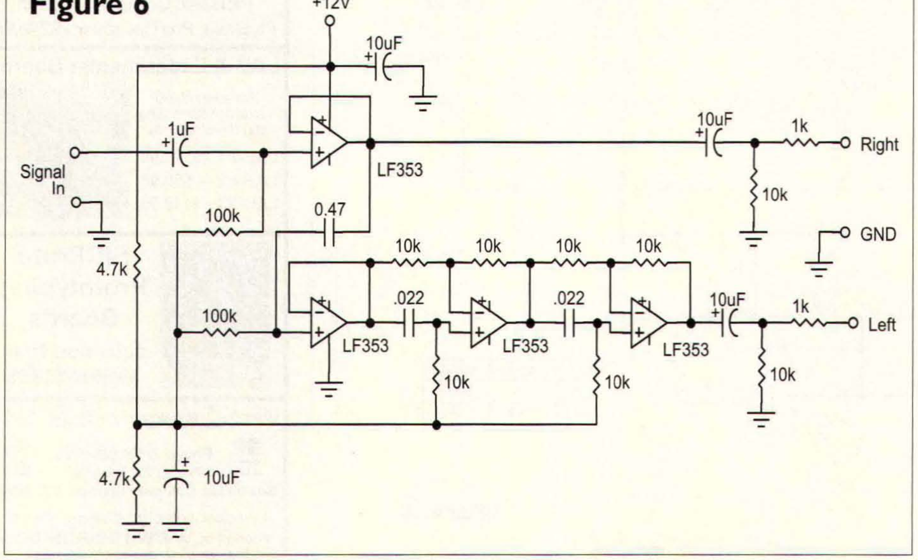
Reversing the phase of the outputs produces the out-of-phase relationship needed to generate a stereo image, and tends to spread out the sound, giving a very basic form of pseudo stereo. While this isn't the perfect stereo simulator (you'll probably notice a hole-in-the-middle effect), it's certainly the easiest to construct and use. If it's better stereo you want, check out the design in the answer below, "Stereo Simulator Uses Phase Shifter."

Stereo Simulator Uses Phase Shifter

Q. I am presently transferring my collection of classical 78 records to CDs for my grandchildren. The problem is that they sound flat when played on their new stereo equipment. I suspect they would appreciate the music more, if I could convert it to stereo. I've seen commercial units, like the AN-2, that purport to make stereo from mono, but I'm not made of money. These records are exactly hi-fi, and I assume a simple circuit should do the job. Can you show me where to start?

A. J.
via Internet

A. The simplest way to convert mono to stereo is to reverse the phase of the signals. In the old days, we did this by reversing the loudspeaker wires. Today, I do it using op-amps, as shown in the previous answer ("Stereo Simulator Uses Phase Inverter"). However, this ploy leaves a lot to be desired in that there's a noticeable absence of sound between the speakers, called

Figure 6


the hole in the middle. A better method is to separate the frequencies, as well as the phase. Stereo simulators like the AN-2 do it using highly-refined comb filters which are expensive and complex in design. Over the years, I've discovered that if you place the low frequencies on the left channel and the higher frequencies on the right, the stereo effect is improved. But the drawback is a boom-box sound to the left coupled with a loud hiss on the right. A compromise between a true comb filter and simple frequency separator is to use a frequency-sensitive phase shifter. (See Figure 6.)

In this design, there are two cascaded phase shifters that work in combination of inverting and non-inverting modes, resulting in unity voltage gain somewhere between zero and 180 degrees of phase shift. By using double inversion, low-end frequencies give no phase change. At middle frequencies, there is about 90 degrees of shift, which is fed to both the left and right speakers to give the stereo effect and, at the same time, fill in the "hole." The center frequency of the phase shifters is about 1 kHz, a frequency to which the human ear is most sensitive.

Colorimeter Uses RGB Sensors

Q. I want to build a circuit like the one at this link: **www.electronic-circuits-diagrams.com/sensorsimages/sensorsckt3.shtml**. I think I can handle the electronics (I'm sort of a beginner), but I'm having a problem finding the color filters. Do you know of an electronic color sensor that can be substituted for the lenses and filters?

Scott
via Internet

A. As a matter of fact, I recently ran across just what the doctor ordered for this design (Figure 8). Taos makes a family of sensors with a built-in color filter of red, blue, and green (**www.taosinc.com/pressrelease_100102.htm**). The output is a linear voltage of 0 to 5 volts, depending on the amount and color of the light falling on the sensor. The logic inputs are configured with inverters to detect the colors the outputs represent. For example, magenta is the presence of red and blue, and the absence of green. By inserting an inverter in the green output, it becomes a logic high when there is no green light, causing the output of the 4073 to go high and light the magenta LED.

LED Auto Taillights

Q. I am making LED taillights for my motor home. It's an older model that has bad wiring, with all the light sockets in bad shape. Besides that, I just like the LED taillights I have seen on trucks and buses. I've been to the truck-repair places and parts houses, but they just don't have what I want. I did learn something that puzzles me, though. On inspection of the units available, I noticed that along with the LEDs and resistors that you would expect, they have a diode 1 or 2. What are they for?

Don McRae
via Internet

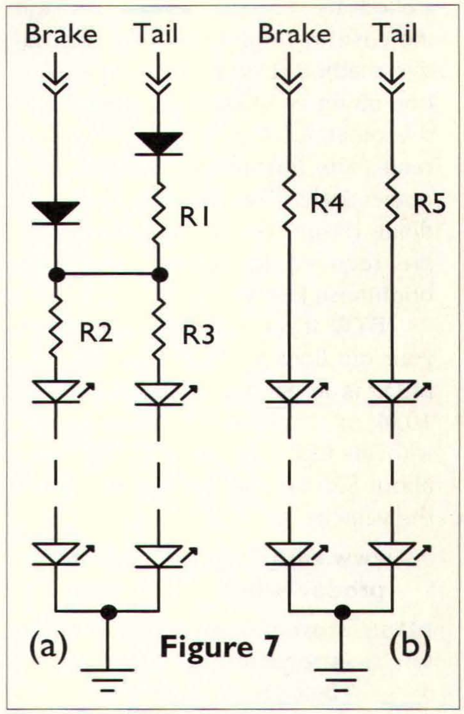


Figure 7

A. My guess is they are steering diodes used to control the taillight brightness between running and braking. Let me demonstrate using Figure 7. The circuit in (a) is probably what you are referring to. When the taillights are on, the current is limited by resistors R1, R2, and R3. When the brake light is applied, the current is limited by R2 and R3, thus bypassing R1. Since LED brightness is con-

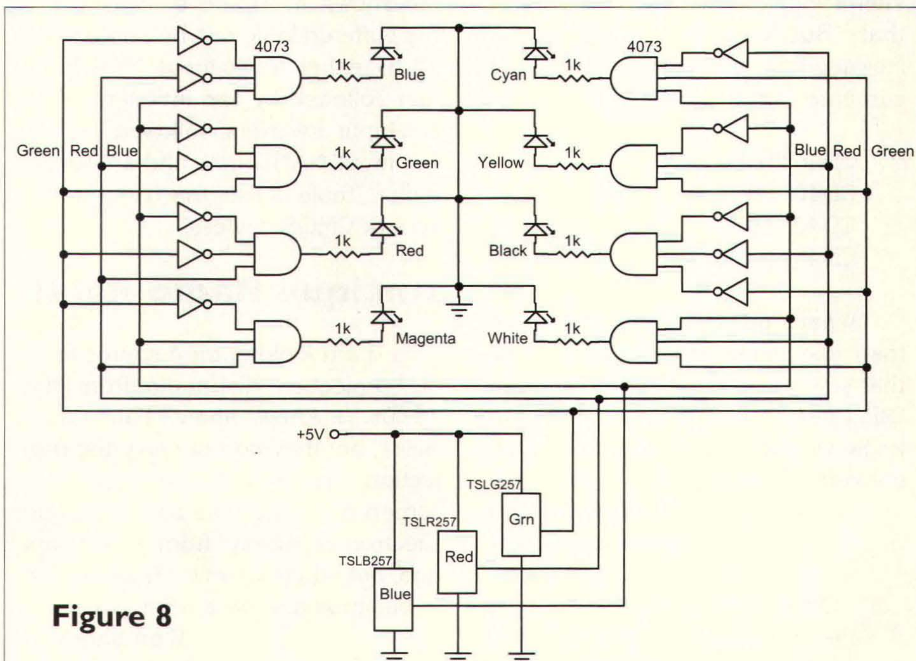


Figure 8

trolled by current, the LEDs will increase in brightness. The alternative method, circuit (b), is to assign one string of LEDs for taillights and the other for brake lights. The currents are limited by R5 and R4, respectively. The advantage of the diode design (a) is that fewer LEDs are required to achieve the same brightness levels.

BTW, if you can repair or replace your old light sockets, upgrading to LEDs is as simple as replacing the 1034 or 1157 incandescent lamps with an LED equivalent. They cost about $25.00 and will last the life of the vehicle. You can buy them from:

www.signaldynamics.com/products/bulbs/1157.asp

http://store.valueaccessories.net/subcatmfgprod.asp?0=222&1=316&2=-1

www.graphicartmotodesign.com/lights/led_e.htm

IC Markings Defined

Q. I am writing to you from the wilds of North Dakota! I use the 4000 series of CMOS integrated circuits, and found your recent comments about changing a sinewave into a squarewave using a CD4011 interesting, and I am going to try just that. But when I looked in my Newark catalog for a CD4011, I came up with these choices.

CD4011BE
CD4011BF
CD4011BM
CD4011UBE

What's going on here? It's more than just packaging because I see that several of these numbers are in DIP. I can find no one that seems to know why there are so many different versions of the same chip.

Lyle A. Nelson
Devils Lake, ND

A. Other than temperature range, the biggest difference between the different types of CMOS gates is in the outputs. Devices with a "B" suffix have buffered outputs and those with a "UB" suffix are unbuffered. What's the difference?

Designation	Temperature Range	Comment
4011BC	-40C to +85C	Commercial version
4011BE	-55C to +125C	Industrial version
4011BF	-40C to +85C	SOIC package
4011BM	-55C to +125C	SOIC package
4011BT	-55C to +125C	Radiation hardened, SOIC
4011UBE	-55C to +125C	Unbuffered version

Table 1

A buffered-CMOS device is one that has an additional gate following the logic device. It exhibits output ON impedance that is independent of any and all valid input logic conditions. Buffered gates have higher gain and noise immunity, but the added buffer increases propagation time (the time it takes the output to react to a change on the input).

Unbuffered-CMOS devices are functionally identical to B-series devices, except that the logical outputs are not buffered and the VIL (logic LOW) and VIH (logic HIGH) specifications are 20% and 80% of VDD, respectively. Unbuffered gates have lower propagation times and faster rise/fall rates.

Logic examples of the buffered and unbuffered two-input NOR gates are shown in Figure 9. Notice that the buffered logic can be implemented by either a two-input NOR function, followed by two inverters or by two-input inverters, followed by the two-input NAND gate and an output buffer. Table 1 lists the different flavors of CMOS devices.

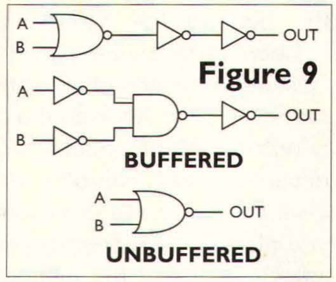


Figure 9

Antique Radio Parts

Q. I am looking for a source for a projection dial radio from the 1930s. I know about Fair Radio Sales, but they do not carry the projection dial film or other parts. I remember the name "Antique Electronics Supply" from a few years ago, but I do not know if they are still in business and have what I need.

Don Sands, II
Davenport, IA

A. Rock Sea Enterprises **(http://members.aol.com/rockseaent)** and D'Antiques Radio/TV **(www.dantiques.com/radio.htm)** are your best bets. You'll find a comprehensive list of antique radio suppliers below. This list is also posted in the PARTFIND file available on our web site **(www.nutsvolts.com)**.

All Things Radio
A comprehensive resource for the antique radio enthusiast.
www.allthingsradio.com

Antique Electronic Supply
800-706-6789
www.tubesandmore.com

D'Antiques Radio/TV hardware items — just what it says.
www.dantiques.com/radio.htm

Fabius Antique Radio
http://members.aol.com/GDevine396

Radio Trader
http://members.aol.com/OLRTmag/main.htm

Links, links, and more links
www.mindspring.com/~cacutts/radio/link/link.html

Nostalgia Air
free on-line schematics and manuals.
www.nostalgiaair.org

Radio Electric Supply
Vacuum tubes
352-332-8881
www.vacuumtubes.net/page/indexc.html

Rock Sea Enterprises
dial scales, decals, plastic overlays from originals.
805-646-7362
http://members.aol.com/rockseaent/

MAILBAG

Dear Mr. Byers:

You had a question in a recent

issue about the "retired guy who fixes scopes," especially Tektronix. That is my close friend, Bob Garcia KD4JRT, of Marietta, GA. They call him "The Scope Man" in hamfest circles. Bob's email is **esaronel@bellsouth.net**. He is very active in both doing expert repair and selling used scopes and test equipment, and his reputation and guarantee are beyond compare.

Allen Bond WB4GNT
via Internet

Dear TJ:

I have a couple of comments for you about the "Sine-to-Square Wave Converter" circuits you proposed in your Dec. 2002 column.

The ±1V swing of the sinewave doesn't provide enough amplitude to get a solid logic 1 into a TTL or CMOS device. It may work under some circumstances, but I wouldn't rely on this type of circuit, even in a hobby circuit. Also, TTL devices — like CMOS chips — shouldn't have their inputs connected to voltages below ground.

You mentioned using an op-amp to offset the ±1V sinewave, and that's a good idea. But instead of simply offsetting the sinewave, amplify it so it swings from, say, 0 to between 4V and 5V. The amplification and offset puts the signal solidly in the logic 0 range and into the logic 1 range for TTL and CMOS chips. Using the amplified sinewave to drive a TTL Schmitt trigger such as an 7414 would do the trick, too.

Jon Titus
Milford, MA

Editor's reply: Hello Jon, long time no hear. Actually that's a typo. I forgot to turn off the default settings on my schematic capture program before submitting this circuit. I caught this right away — in print, the same as you did. Figure 10 is a corrected schematic.

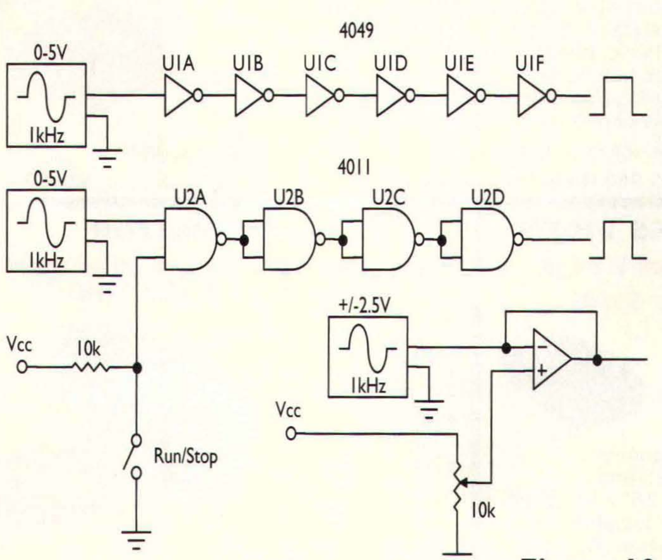


Figure 10

Dear TJ:

Please consider us for your list in PARTFIND.DOC? We are sellers of surplus and refurbished equipment including repair/replacement/experimenter parts and accessories.

We have many hard-to-find electronic items and parts, including a large selection of original manufacturer service manuals and much more geared towards the hobbyist — all at reasonable prices. We are a small family-owned business in operation since 1975 and on the web since 1997. Our web site and catalog is at **www.smcelectronics.com**.

Steven Carlozzi
SMC Electronics

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www.chinesepaintings.com/music/music.htm

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High quality pinhole cameras provide excellent video in nearly undetectable concealments. Range is up to 700 feet with the included receiver. You get the "locked on" crystal clear performance of an IC controlled FM synthesized transmitter design, the efficient 900 megahertz band, combined with the drift-free signal reception of a phase lock loop receiver. All units are operate on 9 volts and use a high quality Panasonic CCD camera. License required for legal operation.
ARS AMATEUR RADIO SERVICE LICENSE REQUIRED
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WCV10-PG B/W Covert Pen Camera $449.95
WCV8-PG Color Covert Cigarette Camera $399.95
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Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Stamp Applications

Gettin' MIDI With It

Well, last month I introduced you to the new PBASIC compiler, so now it's time to have some fun and put it to work. Even though we're going to keep things simple, you'll be able to see that PBASIC 2.5 lets you write cleaner code that's even easier to maintain. You'll probably find — as I have — that you can actually write programs a bit faster because there is no more forward-thinking about **GOTO** labels for **IF-THEN**. Let's get started.

You'd be hard-pressed to find anyone who doesn't like music; in fact, most of us like several varieties. Having experienced the late 60s and early 70s as a youngster, I lean toward what is now called "classic" rock (Led Zeppelin, Jimi Hendrix, etc.), but I also like Classical, Grunge, and even a bit of Rap. Music is probably as old as mankind and is unique in that it not only helps define cultures, it easily crosses cultural boundaries.

Music and electronics go way back, too. Pop quiz: What was the first electronic musical instrument? If you said the theremin, go get yourself a cookie — you win. The theremin was invented in 1919 by Russian physicist Lev Termen (who became Leon Theremin). The theremin became very popular for music and sound-effects in horror and science fiction movies, and even found its way into popular music. (The Beach Boys used a theremin-like instrument on "Good Vibrations" and Led Zeppelin guitarist Jimmy Page frequently used a theremin on stage.)

Since I like music (I can even thrash out a couple Counting Crows songs on my guitar) and I love BASIC Stamps, it just makes sense that I should work with both at the same time. And, in December, I was out in our Rocklin office and saw a Stamp-controlled xylophone that one of my colleagues (Stephen) had created. That same week, I assisted a New York professor who has the interesting occupation of teaching music and technology. Music *and* technology ... that sounds like a lot of fun.

Musical Connections

While the theremin was the first electronic musical instrument, it was (and still is) a specialty device and never became mainstream. The electronic synthesizer, however, is a different story altogether. In the early 1980s, a group of synthesizer manufacturers got together to create a standard that would allow various instruments to connect to and control each other. The standard they created is called MIDI: Musical Instrument Digital Interface.

The MIDI specification (see **www.midi.org**) actually has three components: the protocol, the connection, and a file format. For our part, we're going to focus on the protocol. Of course, we'll also take a look at the connection since our goal is to have the BASIC Stamp play music on a MIDI-compatible instrument.

The MIDI protocol — as it turns out — is very straightforward and easy to implement; even on a small micro like the BASIC Stamp. The protocol transmission scheme is straight serial at 31.25 kBaud; a value we're not generally used to, but not a problem for the BASIC Stamp, since we can calculate and set the *baudmode* parameter of **SEROUT**. For the BS2, the calculation of the *baudmode* parameter is:

INT ((1,000,000 / baud) - 20)

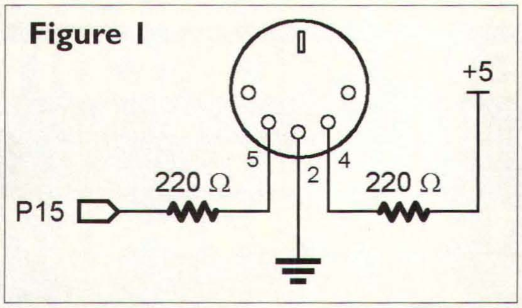
For MIDI we get:

(1,000,000 / 31,250) - 20 = 12

Since the MIDI interface standard uses an optical-isolator on the input that is pulled up by the connecting device, we can run in "open" mode. To do this, we'll add $8000 to the *baudmode*.

Figure 1 shows the connection to the BASIC Stamp. As you can see,

Figure 1



the hardware is a cinch: a couple 220-ohm resistors and a five-pin DIN socket (female). This interface will let you connect your BASIC Stamp to any MIDI instrument using an off-the-shelf MIDI cable (you can pick one up at RadioShack®).

MIDI Messages

MIDI message packets are small; usually a command followed by two data bytes. Since our goal this month is to allow the BASIC Stamp to play music through a MIDI instrument, the two messages we are going to be concerned most with are "Note On" ($90) and "Note Off" ($80).

Here's the syntax:

Note On: $90, note (0 - 127), velocity (0 - 127)
Note Off: $80, note (0 - 127), velocity (0 - 127)

If, for example, we want to send a "Note On" for Middle C at the loudest volume, we would do this:

```
SEROUT 15, $8000+12, [$90, $3C, $7F]
```

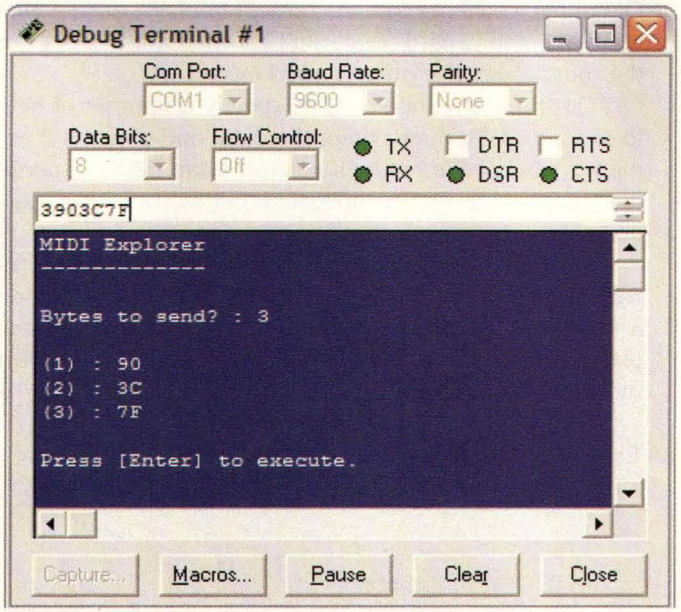
Pretty simple, isn't it? Yes, it is. Let's go ahead and create a program to experiment with sending MIDI messages. Of course, you'll need an instrument to play. I used a MIDI-compatible keyboard (that, until I started this project, was the most expensive guitar tuner I owned ...).

Our program should let us specify a number of bytes to send (1 to 3), then accept the data, and transmit it as a packet when we're ready. If you're new to BASIC Stamps, this may sound a bit complicated, but as you'll see, this is actually a very simple application.

The first part of our program simply clears the **DEBUG** window and displays the title. Notice that there is a short **PAUSE** before the title display. This momentary blank screen serves as a visual cue. We'll get into that more in just a second.

```
Main:
  DO
    DEBUG CLS
    PAUSE 500
    DEBUG "MIDI Explorer", CR
    DEBUG "-------------"
```

As I may have mentioned last month, the new compiler supports some new named constants; many that are used specifically with **DEBUG**. The first that we'll use is **CrsrXY** which positions the **DEBUG** cursor at the column and line values that follow. The next is **ClrDn**. This causes



the **DEBUG** window to clear from the cursor line down.

After clearing any old input, we prompt ourselves for the number of bytes to send, then accept that value from the **DEBUG** window (**SERIN** on pin 16 at 9600 baud).

```
DEBUG CrsrXY, 0, 3, ClrDn
DEBUG "Bytes to send? : "
SERIN 16, 84, [DEC1 nBytes]
```

The following section does most of the work. First, we'll test for a legal *nBytes* value. If the value is okay, we'll loop through the number of bytes and take each one in as a two-digit hex value. Note the use of **CrsrXY** again and accepting serial data from the **DEBUG** window. If the *nBytes* value is out-of-range, the **THEN** portion of **IF-THEN** won't run and the code will **LOOP** back to the beginning (momentary blank screen).

```
IF (nBytes > 0) AND (nBytes <= 3) THEN
  FOR idx = 1 TO nBytes
    DEBUG CrsrXY, 0, (idx + 4)
    DEBUG "(", DEC1 idx, ") : "
    SERIN 16, 84, [HEX2 midi(idx - 1)]
  NEXT
```

With the packet in memory, we'll **WAIT** on the Enter (CR) key to be pressed before sending it.

```
DEBUG CrsrXY, 0, (nBytes + 6)
DEBUG "Press [Enter] to execute. "
SERIN 16, 84, [WAIT (CR)]
```

The last step then, is to send the data. The **STR** modifier and \Length parameter make it easy to send the MIDI data. This works particularly well for us since we may want to change the number of bytes to send.

```
    SEROUT MidiOut, MidiBaud, [STR midi\nBytes]
  ENDIF
LOOP
END
```

Figure 2 shows the program in action. Something interesting that you may find with your instrument that I found with mine is that two consecutive Note On commands for the same note require two Note Off commands. This becomes very apparent with voice selections that don't have natural decay (volume fade).

Okay, if you were able to turn a note on and off, then you can actually play music via your BASIC Stamp. Why would you want to do this? Well, there are a lot of reasons including the fact that there is hardware available that responds to MIDI control signals (lighting, for example).

Stamp-Made Music

If we can send one note at a time, we can send a whole bunch — in a specific order — to play music, right? You betcha.

Like the first, our second program is fairly short (the working part), but this one is just a bit more sophisticated. The purpose of this program is to play music stored in BASIC Stamp **DATA** statements.

The **DATA** statement is one of those features that migrated from "classic" PC BASIC implementations, though the Stamp makes it easier and more functional. Remember that the BASIC Stamp compiler writes the program's **DATA** statements to EEPROM, beginning at address 0 (unless specified otherwise) and building up. Program tokens are stored in the top of the EEPROM and build down. If there is a class between **DATA** and program tokens, the compiler will let you know.

There are several key features of the BASIC Stamp **DATA** statement that make it more flexible than past PC implementations. The feature I take most advantage of is the ability to name DATA locations. Look at this code:

```
Name     DATA    "Jon Williams", 0
Location DATA    "Dallas, TX USA", 0
```

What we've done here is defined two zero-terminated strings. To print a string in the **DEBUG** window, we can use this subroutine:

```
Print_String:
  READ eePntr, char
  IF (char <> 0) THEN
    DEBUG char
    eePntr = eePntr + 1
    GOTO Print_String
  ENDIF
  RETURN
```

The subroutine needs to know where to get characters — the address of the string is put into the variable *eePntr*. So, if we do this:

```
eePntr = Name
GOSUB Print_String
```

... what's actually happening is that the compiler is evaluating the **DATA** statement labels into constant values that represent the EEPROM location of the first character in each string. Given no other **DATA** statements, *Name* evaluates to zero and *Location* evaluates to 13.

Another neat thing about BASIC Stamp **DATA** statements is the ability to store any kind of information that we want. Here's another example:

```
Name     DATA    "Jon
  Williams", 0
Birthday DATA    7, 25
YrOfBirth        DATA
Word 1962
```

As you can see, we've got a string, two Bytes, and a Word (and yes, that's really my birthday — don't forget the cards and gifts!). Actually, all data is stored as Bytes. For character and string data, the ASCII value is stored. For Words, they're stored Little-Endian — that is — low-byte first. As I pointed out last month, PBASIC 2.5 allows us to **READ** a Word with just one operation.

Finally, the information in our **DATA** statements is stored in EEPROM, which means we can change it at run-time with **WRITE**. This allows our program to change information and maintain it even when power is lost.

Sing Me A Song, You're The Stamp-Man

Okay, let's play some music. The reason I spent a moment discussing the details of the **DATA** statement is that's where we're going to keep our song information. The key to this program is *how* we're going to store the song information.

While experimenting, I found that I could actually cause more than one note to play with the same "Note On" command. I simply stacked the note and velocity bytes behind it. Like this:

$90, note1, velocity1, note2, velocity2, note3, velocity3

By playing three notes at a time, I could play simple chords and make something a bit more musical. Okay! In the end, I came up with this storage strategy:

command, notes, timing, note1, velocity1 {, note2, velocity2, note3, velocity3}

Note that the items in curly braces are optional. Here's an actual line from the program's **DATA** table to illustrate:

```
DATA NN, 3, Word N01, 060, 100, 064, 100, 067, 100
```

A few constants are used here. NN is the constant value for Note On ($90). N01 is the constant value for a whole-note duration. This line of **DATA** represents a simple chord made up of the notes C4 (middle C), E4, and G4. All three notes are played at a velocity (volume) of 100.

All right, it's time to look at the program in action. Here's the main program code:

```
Main:
  eePntr = Mystery
  GOSUB Play_Song
  END
```

Really, that's the program — clearly all the work is done in Play_Song and our previous discussion explains the use of *eePntr* and how it indicates one song from many stored in memory. Let's have a look at Play_Song, then we'll go through it step-by-step.

```
Play_Song:
  READ eePntr, cmd
  IF (cmd < $FF) THEN
    READ (eePntr + 1), notes
    READ (eePntr + 2), Word nTime
    FOR idx = 0 TO (notes * 2 - 1)
      READ (eePntr + 4 + idx), midi(idx)
    NEXT
    SEROUT MidiOut, MidiBaud, [cmd, STR midi\(notes * 2)]
    PAUSE nTime
    eePntr = eePntr + 6 + ((notes - 1) * 2)
    GOTO Play_Song
  ENDIF
  RETURN
```

This code is actually quite simple, even if it doesn't appear that way at first glance. We start by reading the command byte. The program will use $FF as an end-of-song indicator, so we have to test for that first. If the command byte is not $FF, the rest of the subroutine will run, otherwise, we **RETURN** to the caller.

Assuming we have a valid command, next up is the number of notes (1 to 3) to play. After the notes is the timing for them. As you can see, we're taking advantage of the new Word modifier for **READ**. The timing value represents the last piece of fixed information. The number of bytes (for notes and velocities) varies; we could have two bytes, four bytes, or six bytes.

A **FOR-NEXT** loop is used to iterate through to the end of this line and store the notes and velocities in an array called *midi*. All that's left to do now is to send the command and data to our MIDI device. Once that's taken care of, we'll use **PAUSE** to create the note duration. We've got music. The last step is to update *eePntr* and go back to the top of Play_Song.

To be honest, the trickiest part of this whole process was converting music into the **DATA** statements. If, for example, we needed to play a C4 and a D4 at the same time, with the C4 being a quarter-note long and the D4 being a half-note long, the **DATA** looks like this:

```
DATA NN, 2, Word N04, 060, 100, 062, 100
DATA NX, 1, Word N04, 060, 000
DATA NX, 1, Word 000, 062, 000
```

Can you see what's happening? The first line strikes both notes and holds them for a quarter-note duration. The second line stops the C4 and holds for an additional quarter-note duration. Remember, the D4 is still playing, so it is now a half-note long. Finally, the D4 is stopped.

I used a demo version of Sonar (from **www.cakewalk.com**) to read a MIDI file and display it in standard musical notation. Thankfully, Sonar has this really neat feature that displays note properties and velocity. The notes are shown as C4, G6, etc. To convert to numeric values, I used a table found at this link:

www.harmonycentral.com/MIDI/Doc/table2.html

I'll tell you what ... the first person to identify the song in the main program will win a BASIC Stamp — a brand-new BS2pe-24. How about that? What that means is you have to download the code, build the interface and let it play. Send me an email with your answer.

Until next time, Happy Valentine's Day and Happy Stamping. **NV**

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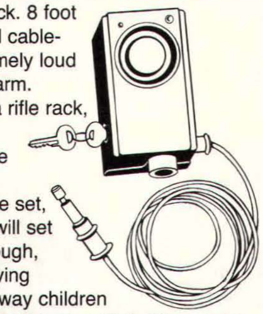

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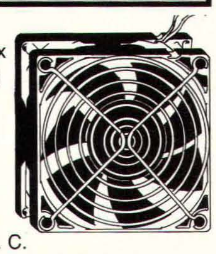

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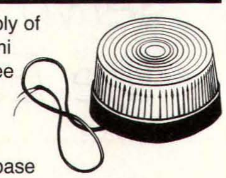

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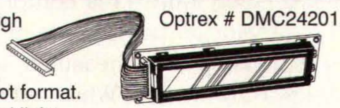

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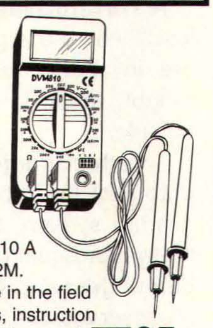

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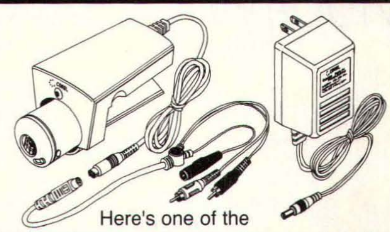

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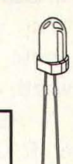

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Modifying an R/C Servo for Continuous Rotation — the Easy Way!

Want a great drive motor for your robot? Look no further than your neighbor's R/C airplane! Inside that exact replica of a Fokker D. III are compact, yet powerful servo motors designed to operate the plane's rudder, ailerons, and other control surfaces. Though intended to be used with a radio transmitter and receiver, these same servos can be controlled electronically using the BASIC Stamp, OOPic, IsoPod, BASIC Atom, BasicX, or most any other microcontroller.

Why an R/C servo motor? They tend to be less expensive than comparable DC gearmotors of the same specification, and they come with their own driver electronics (more about this in a bit). They're definitely worth considering for your next robot.

As it comes out of its packaging, an R/C servo is limited to rotating just half a circle. That's handy for some robot applications, but not too helpful for driving a robot across the floor. Fortunately, it's possible to modify a servo to allow for full continuous rotation. There are a number of methods you can use; the one described here is my favorite. It's relatively quick and easy, requires no soldering or unsoldering, and needs only a minimum number of basic tools.

Inside an R/C Servo

Before getting to the fun hacking bit, let's take a moment to look under the hood of the typical R/C servo. The average, standard-sized R/C servo (see Figure 1) is comprised of three major parts, all contained within a housing that measures 1-1/2 x 3/4 x 1-3/8 inches. While not all servos are this same size, they each contain these three major parts: motor, reduction gear, and control circuit.

Motor. The motor is a small DC-operated permanent magnet unit, capable of reversing direction. This motor may use the common iron core construction, or it may be "coreless," where the permanent magnets are in the center, and the lighter-weight windings rotate around the outside.

Reduction gear. The high speed output of the motor is reduced by a gearing system. Many revolutions of the motor equal one revolution of the output gear and shaft of the servo. In most servos, the output gear turns no more than 90 degrees in either direction. In fact, the final (output) gear of the servo contains a raised nub that physically prevents a larger arc. The typical output speed of an unloaded servo is around 1.0-1.4 revolutions per second. That's about right for the average desktop 'bot.

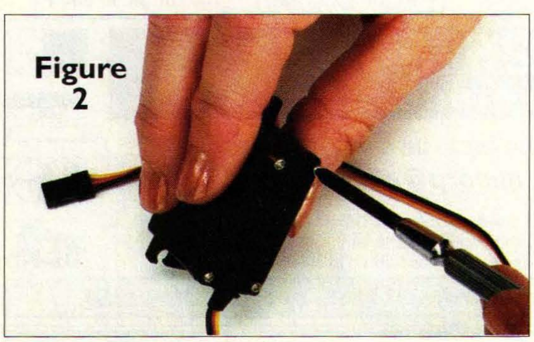

Figure 2

Control circuit. The output gear is connected to a potentiometer — a common electronic device very similar to the volume control on a radio. The potentiometer connects with a control circuit, and the position of the potentiometer indicates the position of the output gear. Most potentiometers have a limited rotation of something less than 360 degrees; the raised nub in the output gear prevents the servo from turning beyond the limits of the potentiometer, which would otherwise damage it.

Figure 1. An R/C servo motor. Photo courtesy Hitec/RCD.

In a radio-control application, the receiver — mounted someplace in the airplane or vehicle — both powers and controls the servo. Most servos made today use a three-wire connection: ground, V+, and signal. The wires are color-coded to identify them, but the colors are not standardized. Usually — but not always — black or brown is ground, red is V+, and the remaining color (white, yellow, orange, blue, etc.) is signal.

All except certain Airtronics servos employ the same wiring sequence, with V+ in the center. In this way, damage to the servo is unlikely if the three-pin connector is reversed. The "old style" Airtronics connector placed ground in the center. Reversing the connector could lead to servo damage. Note that Airtronics makes servos with the older style, as well as a standard wiring configuration. The company refers to the latter as "Z style."

Some of you may know this already, but it's worth reviewing. The control signal for the servo is in the form of a series of pulses. The duration of the pulses is what determines the desired position of the servo. Specifically, the servo is set at its center point if the duration of the control pulse is nominally 1.5 milliseconds (one millisecond is one-thousandth of a second, or 1,000 microseconds). Durations longer or shorter command the servo to turn in one direction or the other. A duration of 1.0 milliseconds (mS) causes the servo to turn all the way in one direction; a duration of 2.0 mS causes the servo to turn all the way in the other direction.

Note that the pulse width variance of 1.0 to 2.0 mS is nominal for most R/C servos, and that the full rotation of a servo is typically 130 to 180 degrees, depending on its mechanical design. Therefore, the actual pulse length of a servo commanded to rotate its full arc will likely extend beyond 1.0-2.0 mS. For example, full rotation (to the stop) for one given make and model of a servo might be 0.730 milliseconds in one direction, and 2.45 milliseconds in the other direction.

The nominal 1.5 millisecond pulse may also not precisely center all makes and models of servos. Slight electrical differences even in servos of the same model may produce minute differences in the centering location.

Modifying Servos for Continuous Rotation

R/C servos are intended for such applications as controlling the steering in a car, or the ailerons in an airplane. They don't need to turn more than 90 or 180 degrees. When a drive motor is required — for the airplane propeller or the rear wheels of a car — a different type of motor is used. For small tabletop robots, these drive motors tend to be both too fast and too expensive. An alternative is to take an R/C servo, and modify it for continuous rotation by removing its internal stops.

By removing the mechanical stops and making a change in the electrical connections inside, it's possible for the output of the servo to turn continuously in either direction. Modified servos are often used for the drive w heels of small robots because their use simplifies both the mechanics and the control electronics of the robot. The servo package includes motor, reduction gearing, and power drive electronics, and can be directly connected to a microcontroller, computer port, or other digital interface.

Alas, while this might sound easy in theory, in practice, the specific design of the various servos on the market can make the modification process a real chore. Not only must the internal stops be disengaged, the potentiometer in the servo must either be removed, or its shaft locked into place.

There are many ways to modify R/C servos:

- Power-train-only mod. For this modification, the control electronics are removed completely, and the motor is driven by an external H-bridge. Any stops are removed from the power train, and the potentiometer is either removed or its shaft otherwise disengaged from the servo drive.
- Signal tap-in mod. In this conversion, the electronics of the servo remain, but as usual, the mechanical stops are removed and the potentiometer is disengaged. In this variation, the robot's computer or microcontroller is connected to the H-bridge chip within the servo's circuitry. Not all servos are so adaptable, however. Several Inter-net sites detail this tapping-in process for the BAL6686 H-bridge IC, used in Futaba and other servos. Do a google.com search for "BAL6686" for a number of useful sites that describe this.
- Potentiometer mod. Here all the control circuitry is left in place, but the potentiometer is either removed completely, or disengaged from the power train. If the potentiometer is removed, a new trimmer pot, or series of two 2.2K ohm resistors, takes its place.

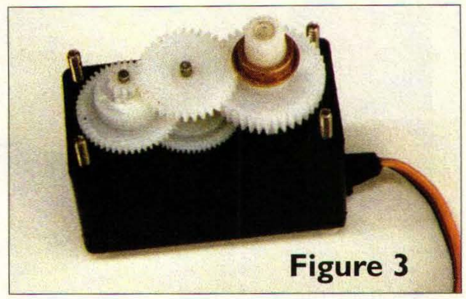
Figure 3

The latter modification is by far the most common. Variations on it have been published in print and on the Internet for over 10 years. The most cited approach involves the Futaba S148 servo (still made, but they are getting harder to find); its potentiometer is replaced by two resistors. A good overview of this approach can be found on the Seattle Robotics User Group web site here: **www.seattlerobotics.org/guide/servohack.html**.

Most potentiometer mods call for soldering in addition to any mechanical changes. However, the design of many servos made today allow for a far less-invasive modification technique, where no soldering or unsoldering is required, and the potentiometer

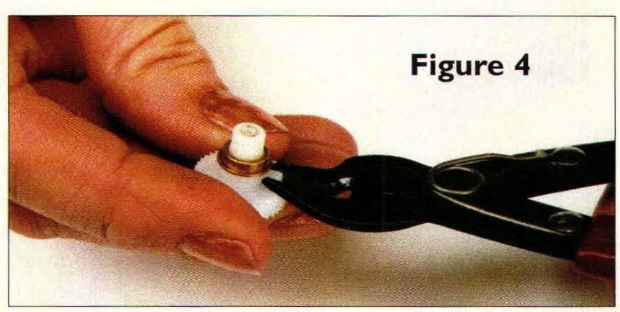
Figure 4

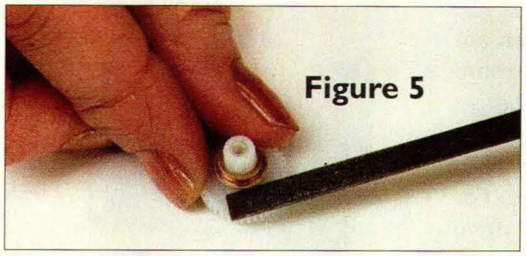

Figure 5

is left in place. Alterations are made only to the output gear of the servo. After you get the hang of it, this mod takes only a minute or two, and requires only basic tools.

The no-solder process involves these basic steps:

1. Remove the four case screws of the servo.

2. Remove just the top case of the servo.

3. Remove the output gear, and cut off the stop nub on its top side.

4. Remove the potentiometer shaft clip from the underside of the output gear. Or, for servos that don't have a shaft clip (these use a molded-in socket that engage with the potentiometer shaft), drill out the bottom of the output gear. This removes the socket so that the potentiometer rotates freely.

5. Make sure the potentiometer is centered.

6. Replace the top of the case and the four screws.

Do note that this modification is not practical with all servos. If the output gear of the servo is supported only by the potentiometer shaft — there's no lower ball bearing or bushing — then this modification isn't recommended. Such servos tend to be the least expensive, and aren't really suitable for modification, anyway. As you can imagine, modifying a servo for full rotation makes it work a lot harder than its manufacturers intended. A servo with no lower bearing or bushing will wear out much faster.

(A lower ball bearing or bushing is merely a metal or even plastic bearing on the underside of the output gear of the servo. This bearing supports the output gear so that the potentiometer does not have to support the load from anything attached to the servo shaft. Servos may also have an upper ball bearing or bushing, which is located on the top of the output gear. Throughout this text, I differentiate between a ball bearing and a bushing, the latter has no rotating parts, and is merely a smooth surface. Bushings can be made of metal, brass, oil-impregnated brass, nylon, and Teflon.)

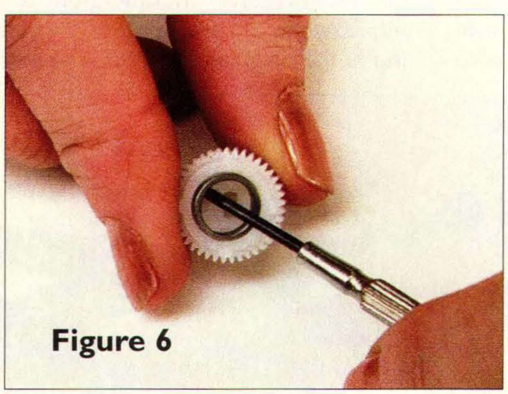

Figure 6

Hands On: Modifying the Hitec HS-422

The Hitec HS-422 is a good example servo to demonstrate the no-solder modification process. The HS-422 is widely available, and retails for under $15.00. It employs both a top and bottom oil-impregnated brass bushing (often referred to as Oilite, a trade name) and a potentiometer shaft clip on the underside of the output gear. Tools needed are:

- #0 Phillips screwdriver
- 1/8" or smaller flat-bladed screwdriver
- "Nippy" cutters, X-ACTO blade, or razor saw
- Small flat jeweler's file

Here are the steps. Before performing the modification, however, test the servo for proper operation, just to be sure it's not bad to begin with. Though rare, some servos fail to work right out of the box.

Throughout the following, use care to avoid wiping off or absorbing through your skin too much of the lubricant used for the servo's internal gears. If you think too much of the lubrication has been lost, you can always add more just prior to reassembly. Clear (or white) gear grease is available at any hobby store that sells R/C parts.

1. Using the Phillips screwdriver, remove the control wheel if it's attached to the output gear/shaft.

2. Untighten the four casing screws from the bottom of the servo (see Figure 2). I recommend you remove the screws completely, so that you can set the servo base down on the table while working inside it. Note that on a few servos, notably the Cirrus CS-71, the case screws are removed from the top.

3. Observe the orientation of all the gears (Figure 3). Remove the center gear, being careful not to unseat its metal shaft. On the HS-422, the center gear cannot be easily removed without also lifting up the output gear. Do so, if needed. Place the center gear aside.

4. Remove the output gear.

5. Using the nippy cutters, X-ACTO blade, or razor saw, remove the nub on the top side of the output gear (refer to Figure 4). I like using the nippy cutters myself, but exercise caution! The harder the plastic, the more likely the nub will break off at high speed. Wear eye protection. Always nip first on the long side, to prevent possible breakage of the output gear. When using an X-ACTO blade or razor saw, the obvious precautions against cutting your fingers off should be observed. Work slowly.

6. Odds are no matter what cutting technique you use, a small portion of the nub will remain. This can be filed down with a small flat file (see Figure 5).

7. Use the small-bladed screwdriver to remove the metal retaining ring from the underside of the output gear (Figure 6). This ring retains the potentiometer shaft clip and serves

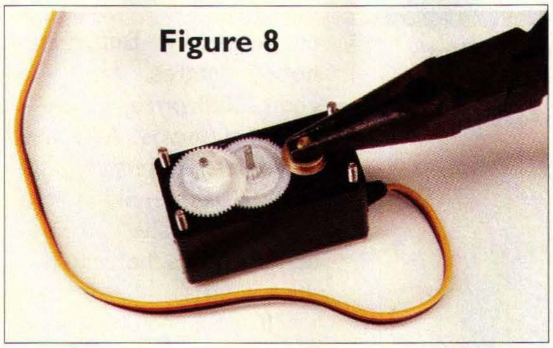
Figure 8

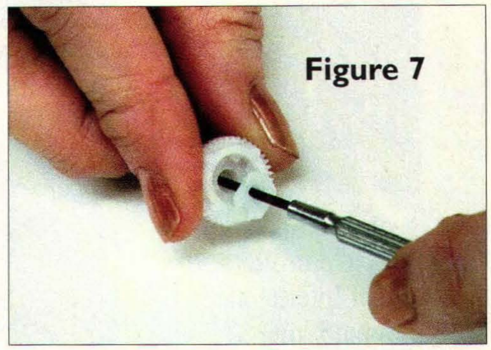
Figure 7

as a bearing surface.

8. Use the small-bladed screwdriver once more to remove the potentiometer shaft clip. See Figure 7.

9. Replace the metal retaining ring back into the output gear.

10. Align the potentiometer shaft so that it's centered (Figure 8). If needed, rotate it back and forth to find the center.

11. As an optional step, you may want to connect the servo to your control circuit. Apply 1.5 mS pulses. If the motor turns (even slowly), rotate the potentiometer shaft until all rotation is "nulled out."

12. Once set to its center, you can leave the shaft as-is, or apply a very small dab of cyanoacrylate glue (Super Glue™) to keep the shaft in place. Do not apply too much glue, or the potentiometer may be damaged.

13. Reassemble by placing the output gear on its seat over the potentiometer. Replace the middle gear, and observe that all gears properly mesh. Add more grease at this point, if needed. Finally, replace the top case and the four case screws.

Test the servo for proper operation by connecting it to your control circuit. A series of 1.5 mS pulses should stop the servo. A nominal signal of 1.0 mS pulses should rotate the servo in one direction; 2.0 mS pulses should rotate the servo in the other direction.

Choosing a Servo to Modify

Now that you know the process of the non-solder servo hack, you can more readily determine which servos are suited to the job. The best servos, from a standpoint of easy modification:

- Use a lower ball bearing or bushing that supports the output gear. At the very least, the output gear should be supported by a molded-in ledge, rather than directly on the potentiometer shaft.
- Use a removable potentiometer shaft clip. The clip can be readily removed in order to disengage the output gear from the potentiometer shaft. Servos that lack a removable clip will use instead a molded-in channel that the potentiometer fits into. This is the case of the Hitec HS-300 and HS-311, and the Futaba S-3003 and S-3004. If your servo is so constructed, you'll need to carefully drill out the bottom of the output gear in order to remove the channel. It's always best to start with small drill bits and work up.
- Use a plastic output gear, rather than a metal gear. The better, heavy-duty servos use a metal output gear. While the metal is able to handle increased stress, it's significantly harder to modify. If your servo of choice uses a metal output gear, a motorized hobby tool such as the Dremel will make the job of grinding down the nub much easier.

Even More Servo Mods

The Internet provides a number of sources for information on how to modify popular standard-size servos. Many are based on removing the potentiometer. In addition to the Seattle Robotics User Group URL noted previously, check out the following:

Al's Robotics
alsrobotics.botic.com

Lynxmotion
www.lynxmotion.com/smodh1.htm
www.lynxmotion.com/smodh2.htm

Robot Store
www.robotstore.com/download/Servo_Mod_Notes_1.0.pdf
(the above requires Adobe Acrobat)

UI Robotics Club
www.indiana.edu/~roboclub/info/servos.html

Sources for Inexpensive Servos

The local hobby store is a great place to find that little do-dad, wheel, or accessory. But many hobby stores tend to charge full price, or close to it, for servos. A typical standard-size servo might cost $20.00, making it a rather expensive proposition to outfit a 'bot with two drive wheels.

If your neighborhood hobby store offers discount prices, all the better. But if it doesn't, you can turn to mail order and online buying. As we wrap up this month's Amateur Robotics column, I leave you with some online stores that sell servos at a discount:

Balsa Products
www.balsapr.com

Reseller of the low-cost Grand Wing servos, including the powerful (but slow) BP148T, rated at 100 oz.-in.

Budget Robotics
www.budgetrobotics.com

Limited selection, but discount prices. Also sells pre-modified servos at a discount. (Disclosure note: this is my company.)

Servo City
www.servocity.com

Reseller of Hitec and Futaba servos.

Tower Hobbies
www.towerhobbies.com

Slightly higher prices than the others, but they have a good selection and customer service. **NV**

Gordon McComb can be reached at **www.budgetrobotics.com/** or **robots@robotoid.com**.


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America's Other Space Program Launches a Rocket and Balloon to Open a New Spaceport


Lift-off

JP Aerospace launched two vehicles into the upper atmosphere over Ft. Stockton, TX, Oct. 5th to inaugurate the new West Texas Spaceport — the first commercial spaceport in Texas. The California-based JP Aerospace will be using the new spaceport as its base for flight operations and will be conducting several more test flights there in the next few months.

PongSats to the Edge of Space

One of the most remarkable ways in which JP Aerospace is opening the space frontier is through its PongSat Program. A PongSat is a science experiment that fits inside a ping-pong ball. Students from grade school through college use their imaginations to create all sorts of science experiments and then seal them inside ping-pong balls. JP Aerospace flies these ping-pong ball "satellites" to the edge of space by balloon or launches them in sounding rockets. After the flight, the experiments are returned to the students. The PongSat Program is an easy and inexpensive way to get students excited about science and engineering. Even the youngest students can be space scientists.


PongSat close-up

MicroSat Launcher Rocket Lifts Off

The opening of the spaceport was culminated by a launch of the MicroSat Launcher Rocket. The purpose of this launch was to work through the regulatory issues governing launches from the spaceport, so that future launches can be expedited.The 12-foot rocket is constructed entirely of carbon fiber except the nose cone, which is a combination of carbon fiber and Kevlar.

When the ignition command was sent, the solid propellant rocket motor provided 4,496 pounds of thrust sending the vehicle to an altitude of 20,000 feet. When the rocket reached peak altitude, it deployed its large black and orange parachute, then floated gently back to Earth. The entire flight lasted just over 10 minutes. The rocket reached a speed of just under Mach two (Mach 1.7).

The MicroSat Launcher Rocket is not destined to take off from the ground. Its launch pad will sit at the edge of the atmosphere at 100,000 feet up. The rocket and the entire 60-foot wide launch platform are carried aloft by 10 helium balloons. When the platform reaches 100,000 feet, the rocket is remotely launched by a ground control station. The rocket will be used to launch small satellites into orbit. This was the third flight of the MicroSat Launcher Rocket.

JP Aerospace / www.jpaerospace.com

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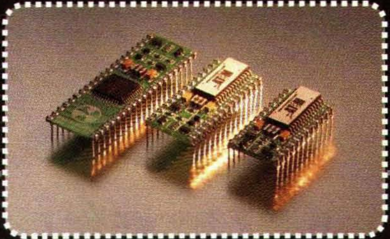

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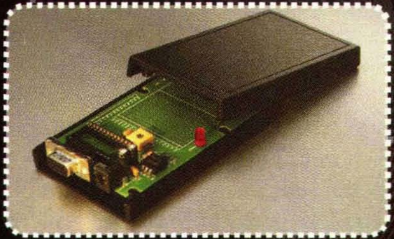

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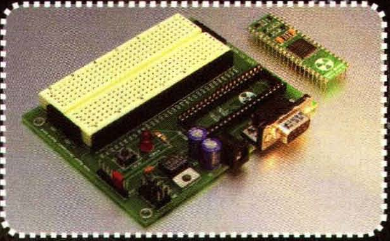

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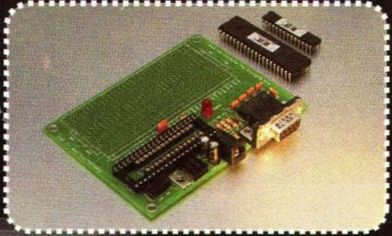

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Texas Instruments and *Nuts & Volts* 2002 MSP430 Ultra-low Power Flash MCU Design Contest 1st Place Winner

Multi-functional Accelerometer

by Jingxi Zhang, Yang Zhang, and Huifang Ni

Introduction

The accelerometer sensor is a device which can detect accelerations caused by either the object's motion (dynamic acceleration) or earth's gravity (static acceleration). It can be packaged as a one-axis, two-axis, or three-axis device to detect linear, two-dimensional, or three-dimensional accelerations, respectively. Combined with a microcontroller, the sensor can be made into a smart device used in many different applications, including orientation detection, security, and computer peripherals.

We constructed a battery-powered, low-cost, handheld multi-functional accelerometer device using a two-axis accelerometer sensor — the ADXL202E from Analog Devices — and an ultra-low power, 16-bit RISC microcontroller — the MSP430F413 from Texas Instruments. The device provides the following six functions, accessible by a selection button:

1. Accurate tilt-angle meter (inclinometer) ranged from -180 to +180° with a resolution of 0.1°.

2. Electronic two-axis bubble level with nine directional indicators.

3. Motion alarm to detect tiny movements or shakes.

4. Pedometer to detect and record a user's walking/running steps.

5. Countdown timer, beeping when the preset time expires.

6. Stopwatch to record time lapse precisely in fractions of seconds.

The low-power ADXL202E is a Micro-Electro-Mechanical System (MEMS) chip. It can measure both dynamic and static acceleration. Besides the analog signal output for each axis, it also contains an output circuit to convert the analog signal to a duty cycle modulated (DCM) signal. The acceleration force (within ±2 g) is linearly proportional to the percentage of the duty cycle of the output signal — T1/T2 — as shown in Figure 1.

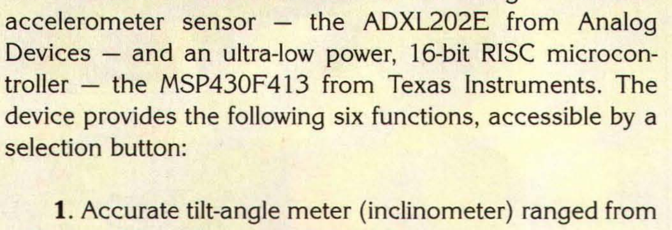


Figure 1. Accelerometer DCM output. Period T1 changes while period T2 keeps constant. The T1/T2 ratio is proportional to the acceleration value detected.

"Texas Instruments congratulates these winners. Their creative ideas took maximum advantage of the ultra-low power Flash memory, high-performance analog peripherals, and modern 16-bit RISC CPU that make the MSP430 unique," states Sara Heaton, Texas Instruments.

Texas Instruments' MSP430 mixed-signal microcontrollers are a family of ultra-low power, 16-bit RISC microcontrollers. The MSP430F413 microcontroller used in this project is one member of the family. It is equipped with a low-power processor (can run up to 8 MHz), 8 KB of instruction flash memory, two segments of 128-byte data flash memory, 256 bytes of RAM, and many peripheral modules. One of the peripheral modules is the versatile, general-purpose, 16-bit timer (Timer_A). The timer can be programmed in capture mode or compare mode. Interrupt events are generated under various conditions. The microcontroller also contains an LCD display driver which handles the analog voltage required for low-voltage LCD displays.

Circuit Description

The circuit schematic is shown in Figure 2. At the center of the circuit is the 64-pin Texas Instruments MSP430F413 microcontroller, U1. The microcontroller provides many built-in peripheral modules. Therefore, very few external components are required to make the circuit work. A low-cost, 32,768 Hz watch crystal, Y1, is used to provide a stable, low-frequency clock reference and synchronize the higher-frequency, on-chip, digitally-controlled oscillator (DCO). The DCO is set to 2 MHz so that a high clock cycle count is provided for Timer_A to capture the accelerometer signals. Because the accelerometer's DCM cycle period is set to 5 mS, the 2 MHz DCO clock rate can provide a maximum of 10,000 clock cycles in T2 — a very high temporal resolution, but one without the need to worry about the clock cycle count overflowing the 16-bit capture register.

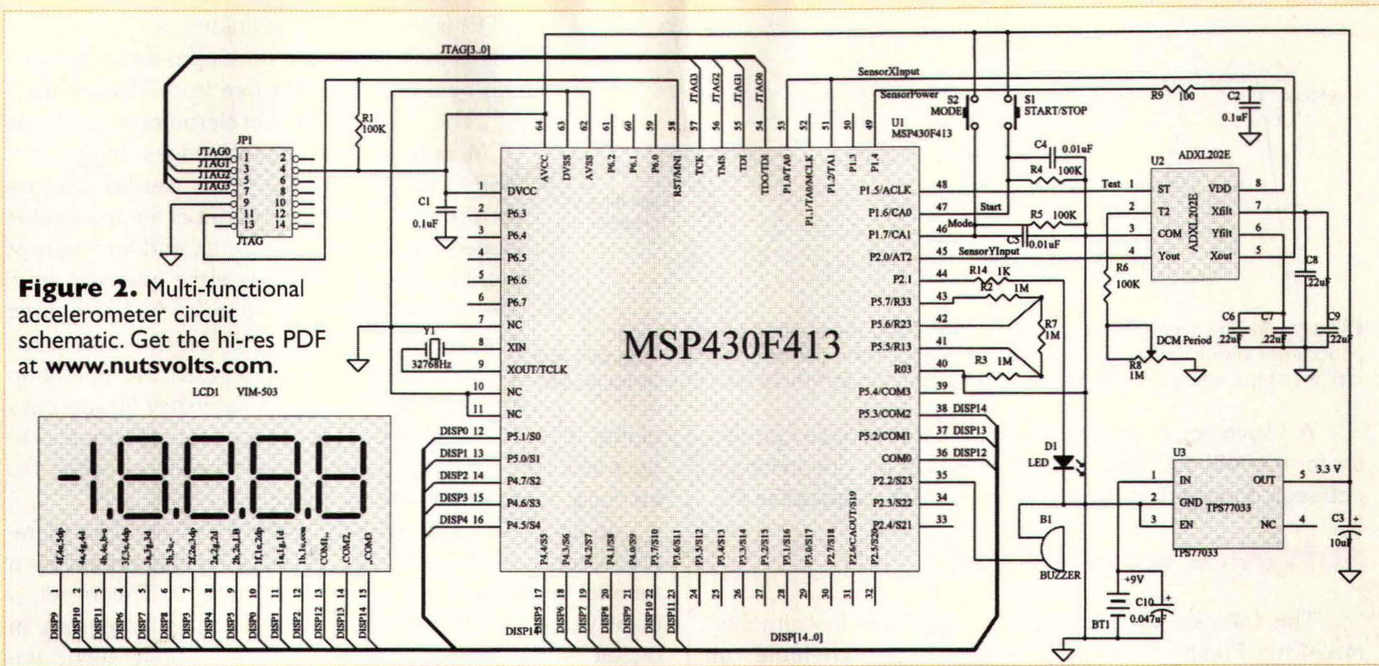


Figure 2. Multi-functional accelerometer circuit schematic. Get the hi-res PDF at **www.nutsvolts.com.**

This high clock rate is also needed for the floating point calculations in our software design. C1 is the bypass capacitor for MSP430F413 and is placed physically close to U1's Vcc pin.

Two normally-open push buttons — S1 and S2 — connect port pins P1.6 and P1.7 to Vcc. The buttons provide rising and falling edge interrupts for mode selection and operation start/stop toggling. Two pull-down resistors — R4 and R5 — insure the I/O pins in low logic level, normally. The two 0.01 µF capacitors — C4 and C5 — tying the I/O pins to ground are for switch debouncing.

The two-axis accelerometer sensor U2, the ADXL202E, is an eight-terminal ceramic leadless chip. It is mounted on the circuit board so that the x-axis is parallel to the major axis of the board and the y-axis is parallel to the minor axis. The two DCM signal outputs — Xout and Yout — are directly connected to MSP430 Timer_A to capture circuit-1 input (AT1/P1.2) and capture circuit-2 input (AT2/P2.0), respectively. The filter capacitors — C6 and C7 — are for Y-channel output, and C8 and C9 are for X-channel output.

These capacitors and a 32K internal resistor on each channel output port compose a low-pass RC filter with the cutoff frequency set to 10 Hz. These 0.22 µF capacitors are used in parallel and could be replaced by one 0.47 µF capacitor for each pair. Resistor R6 and trim pot R8 control the accelerometer DCM cycle period (T2). T2 is set to 5 mS, equivalent to 200 Hz. The sensor's power is supplied by MSP430 pin 49 (P1.4). The accelerometer's sensor does not have a power stand-by mode. To save power consumption when the sensor is not in use, the microcontroller uses this output port to turn the sensor on or off. A 100Ω resistor R9 and a 0.1 µF capacitor C2 decouple high-frequency noise generated by the microcontroller.

Table 1. Calibration Steps

Calibration procedure	LCD display	Device position
1. Calibrate Y axis	"-| |-"	Standup in vertical direction
2. Calibrate X-left	" -| "	Lay on its left
3. Calibrate X-right	" |- "	Lay on its right
4. Calibrate bubble level	"|–|"	Lay on its back

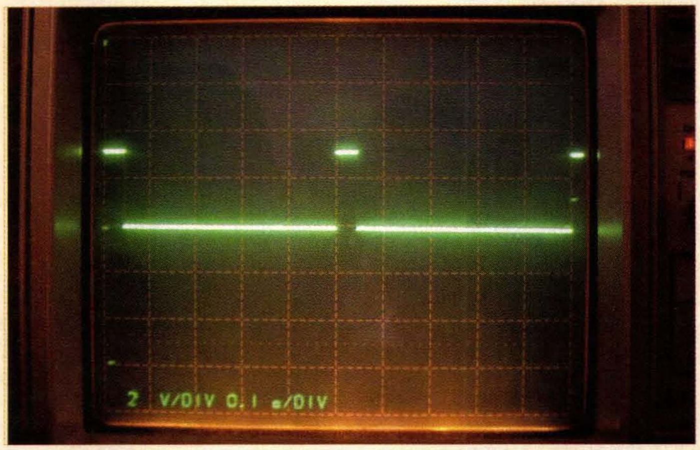


Figure 3. The oscilloscope display shows the power supply for accelerometer sensor ADXL202E (pin 8) in motion alarm operation mode. The sensor is turned on for 40 mS every 500 mS.

Thanks to the built-in LCD driver, a 15-pin, 3-MUX, low-voltage LCD display (VIM-503-DP-RC-S) is directly connected to the MSP430 (pins of port3, port4, and port5). An equally-weighted resistor (1M) ladder constructed by R2, R3, and R7 is for LCD analog voltage generation. The LCD frame refresh rate is set to 40 Hz. An LED and a buzzer are connected to U1 pins P2.1 and P2.2, respectively, to provide the user with a visual and audible alert.

The system's power supply is managed by the TPS77033, an ultra-low power, low-dropout, linear regulator from Texas Instruments (U3). It converts a nine-volt battery to a 3.3-volt power supply for the MSP430. The TPS77033's quiescent current is about 17 µA. There is no power switch in the circuit. When the device is not in use for 20 seconds, the microcontroller enters LPM4 with the power supply current dropped to 0.1 µA. The main current consumption is the TPS77033 quiescent current in this mode. A 500 mAh, nine-volt battery can last about 500 mAh/17 µA = 29,411 hours = 3.4 years. C3 is the output capacitor and C10 is the input bypass capacitor.

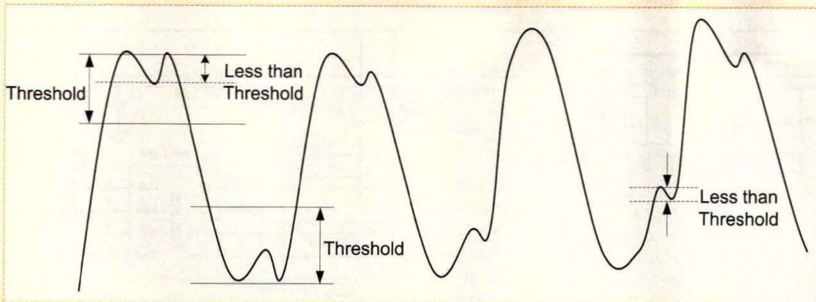


Figure 4. The accelerometer's y-axis output and threshold discrimination in pedometer mode. The movement outputs that exceed the threshold are counted as walking steps, while the small fluctuations under the threshold are considered noise.

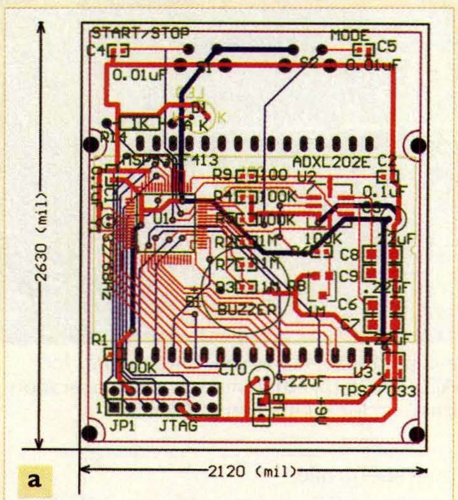
(FPP) is required in the linking procedure. The FPP is included in the development toolkit and can be downloaded for free from TI's website.

The ADXL202E accelerometer dual-axis DCM outputs' on and off edges trigger the MSP430F413 Timer_A (it is set to capture mode). The clock-cycle count of each output is logged into a capture register, and an interrupt event is generated to evoke the interrupt service routine (ISR). The duty-cycle percentage represented in clock-cycle counts is converted to acceleration. Dependent on the operation mode, a second-order Chebyshev IIR low-pass digital filter is applied to the acceleration signals to decrease the accelerometer's floor noise in order to increase its resolution and accuracy.

A 14-pin box header JP1 is the JTAG interface connector for the MSP430 flash emulation tool to provide in-circuit debugging and programming using an IBM-compatible PC.

Software Description

The software was developed using Texas Instruments' MSP430 Flash Emulation Tool (FET; available at **www.ti.com**). The assembly source code is available at the FTP site. Because the program contains digital filtering and trigonometric calculations, the TI floating point package



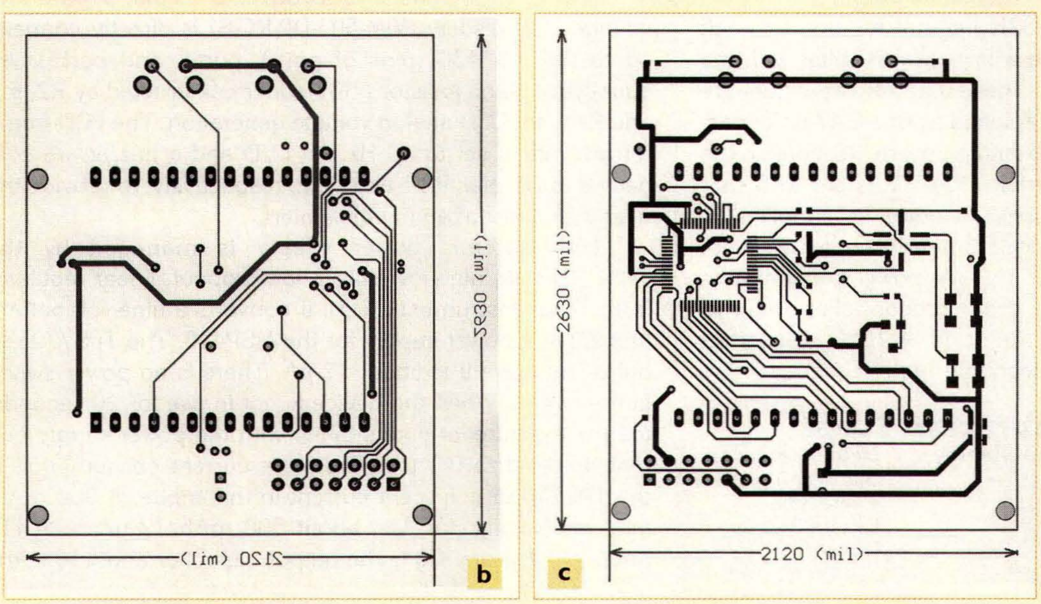


Figure 5. Printed circuit board layouts.

5a is the multi-layer printout as a parts placement guide.

5b is the top layer (component side) foil pattern.

5c is the bottom layer foil pattern.

In tilt-angle meter mode, the dual-axis filtered acceleration signals are converted to an angle measurement by a rational arctangent approximation method. The result is displayed in the LCD module as the tilt angle in degrees. In digital bubble-level mode, the dual-axis accelerations are compared to values pre-stored in Flash memory during the calibration procedure. The resulting differences drive the LCD module to display one of nine directional symbols to indicate the bubble direction. The motion alarm operation uses unfiltered, raw accelerations to preserve the wider frequency response for higher-frequency movement.

To prolong the battery life, the microprocessor sleeps in low-power mode (LPM3) and wakes up for 40 mS to detect the acceleration changes repeatedly in 500 mS intervals (Figure 3). In pedometer mode, only one axis — the y-axis — detects the user's up-and-down movement during walk or run.

The low-pass filtered signal goes through a peak detection procedure. After a peak is detected, a preset threshold is used to determine if the movement wave is noise or a true walking movement (Figure 4). Since the device implements many basic functions — such as independent virtual timers, the buzzer driver, the binary-to-BCD converter, and the LCD display driver — it is very easy to reuse these function blocks to add countdown timer and stopwatch operations, although they do not use the accelerometer sensor.

Project Construction

All parts (see Parts List), except the accelerometer ADXL202E can be purchased from Digi-Key (**www.digikey.com**). The accelerometer can be obtained from Analog Devices, Inc. (**www.analog.com**). The total cost of the parts is under $50.00. The electronics components are mounted on a 2.12 x 2.63 inch, two-layer printed circuit board (PCB). Figure 5 is the PCB layout. The LCD is mounted on the circuit side. The plastic enclosure is Serpace M-6 mode, which contains a nine-volt battery compartment. A window is cut out on the front panel for the LCD display.

Surface-mount (SMT) components are used in this project (Figure 6). A fine-tip solder gun and a lamp with magnifier lenses are suggested for soldering the components on the PCB. First, solder all the surface-mount components, including the microprocessor MSP430F413, accelerometer ADXL202E, linear regulator TPS77033, chip capacitors, and resistors on the PCB's top side. Apply a small amount of flux onto the pads before soldering. Keep soldering time short to avoid damaging the parts.

Because the MSP430F413 is packaged with a very fine pin pitch, care should be taken when the chip is soldered. Use minimal solder to avoid bridging the pins together. The best way from our experience is to tin the chip pins and PCB pads first, and then lightly press the pins onto the pads by the solder gun tip with no extra solder. After aligning the pins to the pad, solder the two pins in opposite corners first to fix the chip in place on the board, and then solder the rest of the pins.

The second step is to solder the thru-hole component parts, including the crystal, electrolytic capacitors, push-button switches, 14-pin header, and LED. Note that the LED is mounted on the PCB's bottom side. The next step is to solder the buzzer. Because the buzzer is going to cover some other parts, make sure those components beneath the buzzer are in place before soldering the buzzer on the board. The last step is to solder the LCD display on the PCB bottom side. Note that Digi-Key carries only the high-voltage mode of VIM-503 (VIM-503-DP-RC-S-HV), which displays very low contrast in three-volt applications. You may get the low-voltage mode VIM-503-DP-RC-S from Varitronix (**www.Varitronix.com**). If the contrast is too high, you may modify the circuit to smoothen the contrast by disconnecting U1 pin 40 (R03) from ground (with R3 still connected to U1 pin 40) and re-connecting U1 pin 40 to ground through a 200K resistor.

After constructing the hardware, it is time to program the microcontroller. Connect JP1 to the FET by a 14-conductor cable as shown in Figure 7. The FET is connected to the parallel port of a host computer. Launch the IRA embedded workbench, which is included in the TI MSP430 software

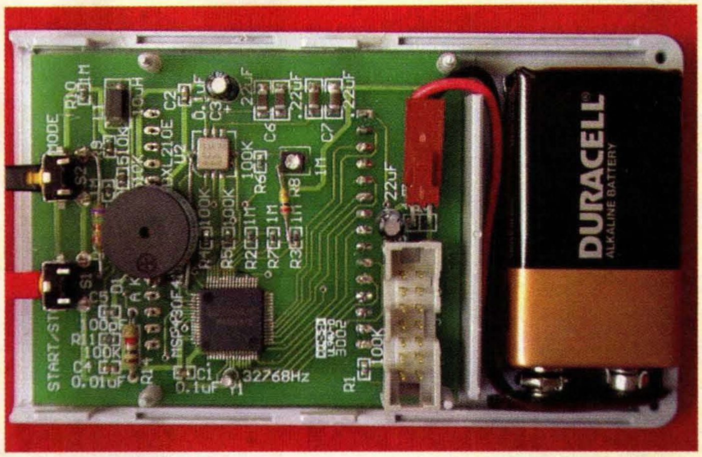


Figure 6. The top view of the circuit board. Surface-mount components are used on the board.

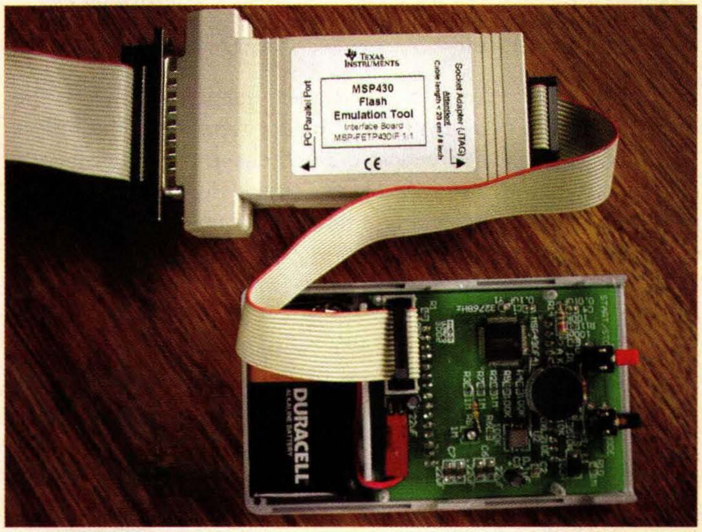


Figure 7. The circuit board is connected to the FET by a 14-conductor cable. The FET is connected to the parallel port of a host computer.

development toolkits. Find the TI floating point package (FPP), which is in the directory "Program Files\IAR Systems\ew23\430\Fpp410\IAR" if your TI MSP430 development CD is the same version as ours. Compile the FPP source code if the FPP.r43 is not ready. A library type of FPP is required for the accelerometer software, which can be obtained either by setting the "Make a LIBRARY module" option in the FPP project assembler settings or by using the

Parts List for Multi-Functional Accelerometer Circuit

Semiconductors
U1 - Texas Instruments MSP430F413 ultra-low power, 16-bit RISC microcontrollers
U2 - Analog Devices ADXL202E low-cost ±2 g dual-axis accelerometer
U3 - Texas Instruments TPS77033 ultra-low power 50-mA low-dropout linear regulator
D1 - Any standard light emitting diode

Resistors
R1, R4, R5, R6 - 100K, SMT 0603, 5%
R2, R3, R7 - 1M, SMT 0603, 5%
R8 - 1M, 3 mm square SMT trimmer potentiometer
R9 - 10Ω, SMT 0603, 5%
R14 - 1K, 1/8 watt, 10%

Capacitors
C1, C2 - 0.1µF, SMT 0603, 20%
C3 - 10µF aluminum electrolytic capacitor, 6.3V, 10%
C4, C5 - 0.047µF, SMT 0603, 10%
C6, C7, C8, C9 - 0.22µF, SMT 1206, 10%
C10 - 0.047~10µF, aluminum electrolytic capacitor, 25V

Additional Parts and Materials
Y1 - 32768 Hz Crystal (ECS-2X6)
B1 - Piezo-electric Buzzer, 3-12V, 13.7 mm PCB mount
JP1 - 14-pin 0.1" x 0.1" shrouded header, Digi-Key part number MHB14K-ND
S1, S2 - Miniature 6mm x 6mm tactile switch
LCD1 - 4-1/2 Digits 0.4" Numeric LCD display (Varitronix VIM-503-DP-RC-S)
Case - Serpace M-6 plastic enclosure
Battery - Alkaline nine-volt

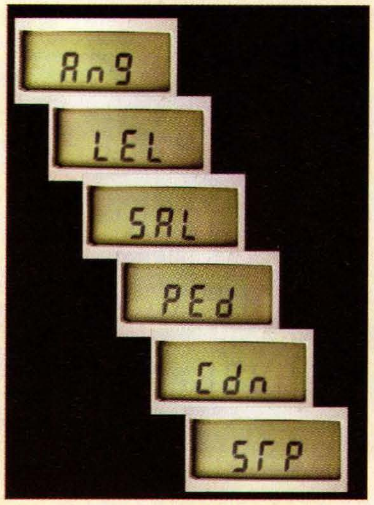


Figure 8. The LCD displays of each operation mode. The operation modes rotate in the order shown.

Figure 9. The measured angle is displayed on the LCD as degrees in tilt-angle meter mode.

"make-library" command in XLIB utility to convert the FPP.r43 from program type to library type. After the FPP is ready, compile the accelerometer assembly source code and link it with the FPP library in the development workbench (put the assembly source code and FPP.r43 in the same project). If there is no error, you can then load the executable code into MSP430F413 by selecting "Debugger" from the Project menu. After a few seconds, the loading process is finished and a CSPY debugger window is opened. Click the "Go" button in the toolbar. Voila! You have the multi-function accelerometer running on your workbench.

Operation and Testing

Now the device is ready for you to test. There is no power switch for this device. Any button activity will turn on the device. The first step is to test the mode selection switch button S2. By pushing S2, you should see the LCD display current operation mode. If you push S2 again, within three seconds, the current operation will switch to next mode. The operation cycle is as follows: as tilt-angle meter (Ang)

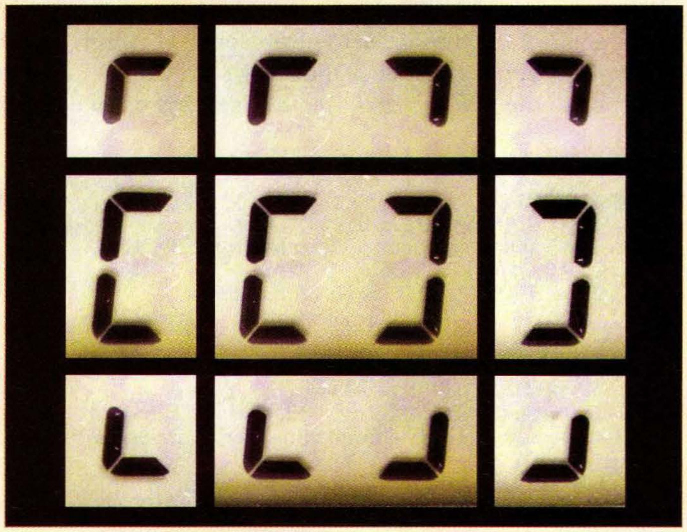


Figure 10. The nine LCD indicators of bubble-level operation. When the device is leveled in both axes, the center indicator is displayed.

→ bubble level (LEL) → motion and shock alarm (SAL) → pedometer (PED) → countdown timer (Cnd) → Stopwatch (STP) → back to tilt-angle meter as shown in Figure 8.

A calibration procedure is needed before running all the functions accurately. Push S2 and hold it for more than three seconds (in any operation mode). The LED is blinking and the device enters the calibration mode. You can use gravity as the acceleration force to calibrate the device. Four steps in calibration need to be complete as shown in Table 1. For each step, place the device on a level surface in the described position and push the start button. The microcontroller gets 16 samples on each step for each axis, and the average value is stored in flash memory (segment A) to be used as reference. The calibration procedure can be performed repeatedly, if necessary. Note: the DCM output cycle period at U2 pin 4 is adjusted to about 5 mS by trim pot R8 (about 500K).

In the tilt-angle meter operation mode, push button S1 once the LED is lit: the current angle in degrees is continuously displayed on the LCD as shown in Figure 9. Push button S1 again; the operation is stopped and the LED is turned off. The last angle readout stays on the LCD for 20 seconds before the device automatically turns off.

For the bubble-level operation mode, lay the device face up on the surface. One of the nine directional indicators (Figure 10) is displayed on the LCD indicating the bubble position.

In motion alarm mode, when the operation is activated by pushing button S1, there is a 10-second delay before the device is armed. The LED indicates the delay period. Within these 10 seconds, the user can push the button S2 repeatedly to enter a number between 0 and 9 as a key code (the default key code is 0). Any tiny movement or shake after the device is armed will trigger the alarm. To shut down the alarm after it goes off, you must use button S2 to enter the matching number, and then push the stop button.

In pedometer and stopwatch modes, the operation is straightforward. Pushing button S1 toggles the operation on and off. On each start, the count will be reset to zero.

In countdown timer mode, pushing button S1 once enters the set-up stage (LED blinking). A time from 1 to 15 minutes can be entered by pushing button S2 repeatedly. Pushing button S1 again begins the countdown procedure. When the set time expires, the device beeps three times to alert the user.

If all operation modes tested work as expected, you can remove the FET cable from JP1. The device is ready for use. If the device cannot start after you remove the cable, you can remove the battery. Use a wire to short the power terminal to discharge the remaining charge on C10. Then reconnect the battery back, and the device should be back to functioning. **NV**

Biography
Jingxi Zhang — Graduated from Zhongshang Medical University, Guangzhou, China. He obtained his MS in EE at UC Irvine, CA, and his PhD in Neurosciences at UCLA, CA. He is currently the Chief Technologist at JVC Laboratory of America, Santa Clara, CA. Yang Zhang — An undergraduate studying EE and CS at UC Berkeley, CA. Huifang Ni — Currently works at Elan Pharmaceuticals, South San Francisco, CA.

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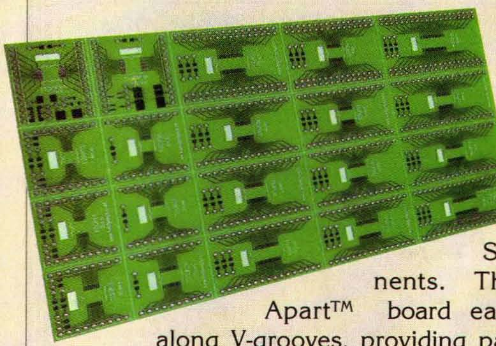
SNAP-APART™ ADAPTER BOARD MAKES SMT BREADBOARDING EASY



Bellin Dynamic Systems introduces an easy, economic alternative to breadboarding TSSOP and SSOP components. The P507 Snap-Apart™ board easily snaps apart along V-grooves, providing patterns with up to 40 pads on both sides of the board. Popular .65mm, .5mm, and .4mm pin pitches are available. Silk screen and solder mask provide a neat, professional look for breadboarding projects.

Components without DIP package equivalents may be breadboarded in minutes using only a standard soldering iron. Rapid SMT breadboarding capability provided by the P507 can often reduce circuit board revisions during project development.

The P507 is the latest in the P500 series product line, which includes Snap-Apart boards for SOIC, PLCC, QFP, SOT, SC, DPAK, and other surface-mount components.

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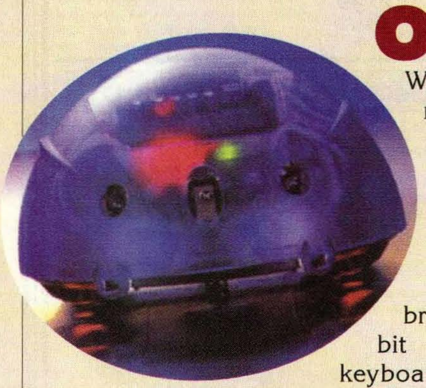
WAO "CRANIUM" PROGRAMMABLE ROBOT KIT



OWI introduces the fourth generation of WAO programmable robot kits and wow is it spectacular! WAO Cranium is a two-wheeled robot that you can program without a personal computer.

The intellectual brain consists of an eight-bit microcontroller and keyboard with 33 tactile buttons. This bundle of brains can store up to 60 programming steps and 30 FOR-NEXT multiplex loops. In addition to its futuristic and powerful design, it features six vision sensors to see in front and below the robot. The "eyes" that enable it to see in front of itself have two infrared LEDs and an infrared detector IC. Four floor light sensors (CdS sensor) will enable it to distinguish the contrast of light underneath its shell.

Dr. OWIKIT says this robot is more than just fun. Assembling, building, and following instructions help develop fine motor skills and hand-eye coordination. Because it's programmable, one has to plan ahead, think systematically and logically, develop problem-solving skills, and will challenge you to think creatively.

Easy to assemble, this OWIKIT Intermediate building level robot makes a great entrant for robotic competitions, robotic workshops, after-school programs, special events, gifts, science enrichment camps, and classroom activities.

Suggested selling price is $119.95 USD.

For more information, contact:

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17141 Kingsview Ave., Dept. NV
Carson, CA 90746
Tel: **310-515-1900**
Fax: **310-515-1606**
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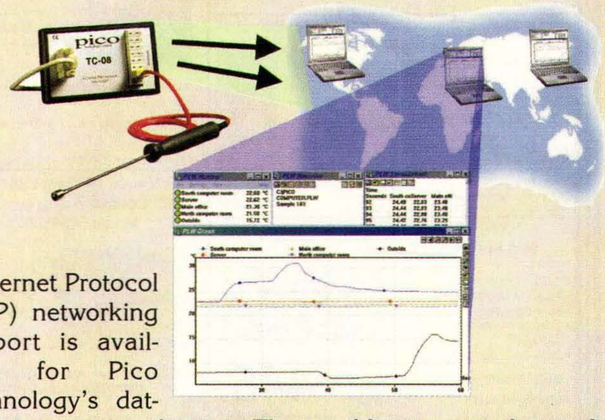
Web: **www.owirobot.com**

INTERNET DATA ACQUISITION FOR PC-ADAPTERS



Internet Protocol (IP) networking support is available for Pico Technology's datalogging scope adapters. This enables remote data collection from Pico Technology's full range of data acquisition products.

Previously, cost has been prohibitive for most remote data acquisition applications. But using IP networking, it is now possible to transfer measurements from a remote site via an existing LAN, company network, or even over the Internet at very little cost.

PicoLog software is ideal for short-term or intermittent voltage data acquisition, whereas the EnviroMon system provides reliable, continuous, long-term data acquisition for temperature and other environmental measurements.

PicoLog can also access Pico Technology's high-resolution voltage measuring devices, like the 12-bit ADC12 or 16-bit ADC16, general-purpose devices, such as the 11-channel ADC11, and high-speed conditioners like the 100Ms/S ADC200 and ADC212. Now you can run Pico Technology's economical data logging equipment locally and then remotely access these devices from another computer.

PicoLog software is available at no charge with the purchase of Pico Technology scope adapters, which are available from $95.00 (stock).

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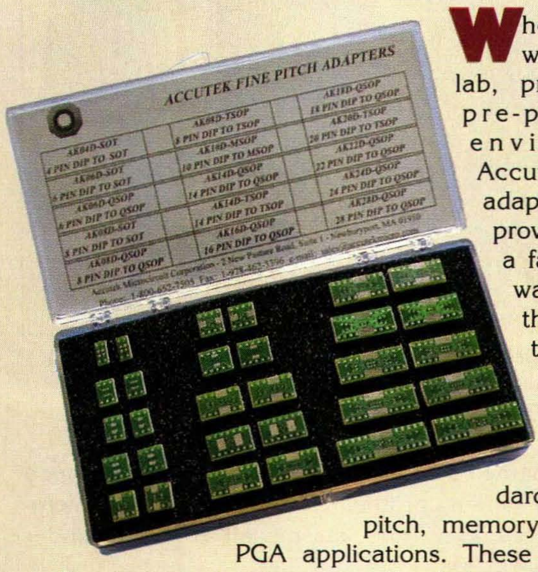
LOOKING FOR THE QUICKEST WAY TO PROTOTYPE?



Whether you're working in a lab, prototype, or pre-production environment, Accutek's new adapter kits can provide you with a fast and easy way to move through prototyping. We have surface-mount adapter kits for: standard pitch, fine pitch, memory, and PLCC-PGA applications. These kits convert surface-mount components to thru-hole and are an ideal tool for developers who are looking to streamline the prototype to production process.

Potential applications include: Universities, Physics Labs, Military COTS, Medical, Aerospace, Research and Development, and Product Development.

Kits are available with gold or solder-plated machined pins or phosphor bronze solder tinned flat contact pins. The kits adapt surface-mount IC packages such as SOIC, TSOP, QSOP, MSOP, and SOJ to pin-compatible DIP modules in pin counts ranging from 4-48 pins.

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LaneAlert — A Driver's Best Friend

This Month's Projects

The Fuzzball Rating System

To find out the level of difficulty for each of these projects, turn to Fuzzball for the answers.

The scale is from 1-4, with four Fuzzballs being the more difficult or advanced projects. Just look for the Fuzzballs in the opening header.

You'll also find information included with each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!

Stay "Alert" at the wheel with this effective lane detection device.

The technology age

It happens all too often: a driver falls asleep at the wheel, veers off the road, and narrowly escapes a fatal injury. You might think in this day and age of high-tech devices and fast-paced lifestyles, that kind of scenario would be a thing of the past. After all, it's the 21st century. Cars come equipped with all kinds of gizmos: seat belts, air bags, and anti-lock brakes. And, for those like myself who can be sometimes directionally impaired, GPS navigation systems help get us from A to B.

Why shouldn't vehicles also come equipped with road-sensing devices that detect when the car is drifting out of its lane on the highway? Technological advances make this idea a definite possibility. In fact, there are several patents on the books that describe such devices. Unfortunately, they are relatively complex and expensive to implement in the average vehicle, employing digital image sensors and complex frame processing algorithms. The expense puts this type of system out of reach of the average driver, at least for now.

In the meantime, you may be surprised to discover that there's a simpler solution to the problem. Employing some readily-available and relatively-inexpensive components, you can create your own lane-detection system. I named the device "LaneAlert" and developed a working prototype including sensors, micro-controller, and alarm, all for well under $100.00.

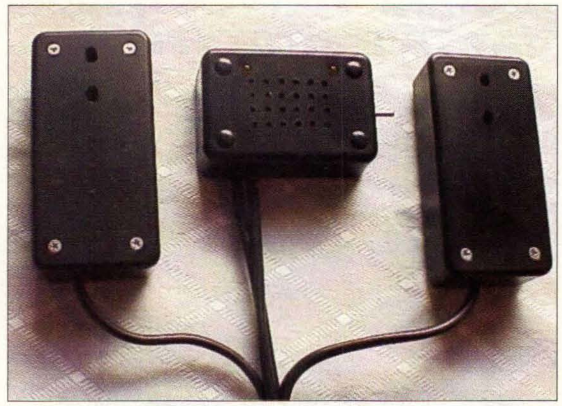


Figure 1: LaneAlert — lane detection system including computer module (center) and two sensor modules (left and right).

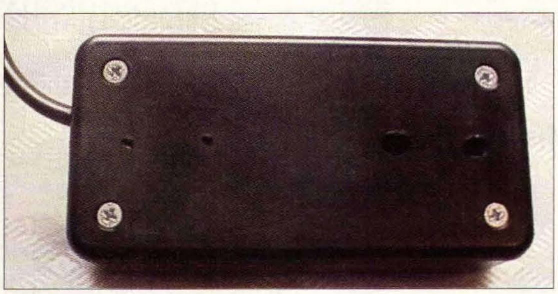


Figure 2: Sensor module — underside view showing cover and four aperture holes.

Let me say at the outset that LaneAlert is an experimental device meant to be a driver's aid. It is not intended to replace common-sense driving safety habits. The design was proven in daytime conditions. "But what about night driving?" you might be asking. Night testing presents some interesting challenges that we're not ready to tackle in this article. For now, we want to focus on the design and construction. We'll also do some testing, but in daytime conditions for convenience and simplicity.

Ready to operate

The unit offers two operational modes: alarm-enabled and mute. The three-position toggle switch selects the mode. This type of switch offers two "on" positions and a center "off" position. One position activates the device and enables the piezo buzzer (the alarm). Another position also activates the device, but disables the piezo (mute). When

Tools:
Parallax BASIC Stamp Development System
Soldering iron
Electric drill and bits
Multimeter

Skills:
Basic electronic assembly skills
Beginner level programming skills

testing, it's helpful to run mute and simply view the indicator LEDs. When the unit is activated, the LEDs turn on briefly and then extinguish within a second or so. After the brief initialization sequence, the unit begins scanning. When lane markings are found, the left and/or right LED illuminates to indicate the sensor that detected them. Actually, what the device is looking for are sharp changes in contrast. If either or both sensors "see" these changes, all is well and the device continues to scan. But if neither sensor detects a contrast within a three-second period, the alarm will sound. The unit then resets itself automatically, cancels the alarm, and begins scanning once again.

When testing in daylight, there are some variables to consider. One such variable is shadowing. When driving, shadows are detected as changes in contrast and could cause alarms. For the most part, this will not be a factor when driving at night. Another consideration is the situation that results when you're driving on a road that has dimly visible road markings such as back roads or alleys. In this instance, LaneAlert may not function properly. However, you must remember that the device's usefulness is best realized on long trips when driving state and interstate highways. In most cases, these roads should be well maintained and clearly marked.

Construction

LaneAlert consists of three modules, each housed in a black plastic project box: a computer module and two sensor modules. Each sensor module is attached to the computer module by an eight foot length of four-conductor telephone cable. These sensors are located on either side of the vehicle, mounted under the sideview mirrors, and held in place with adhesive-backed Velcro.

The sensor modules view the road for lane markings. Figure 2 shows the under-side view of a sensor module. Four screws hold the cover in place. The cover is drilled with light-entry holes, known as apertures. The amount of light entering the sensor module is important. In much the same way the pupil of the eye regulates light, we must ensure the internal photocell sensors receive the right amount of light. The diameter of the apertures greatly depends on the outdoor lighting you'll be testing under. You'll want to test the device in sunlit conditions initially. I recommend holes no

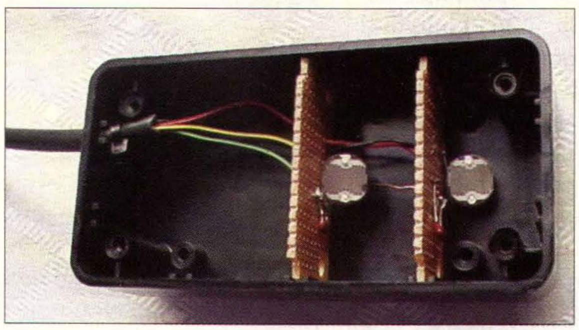


Figure 3: Sensor module with cover removed, exposing perf boards with photocells.

Figure 4: Computer module has two indicator LEDs. Small holes are drilled for the piezo alarm.

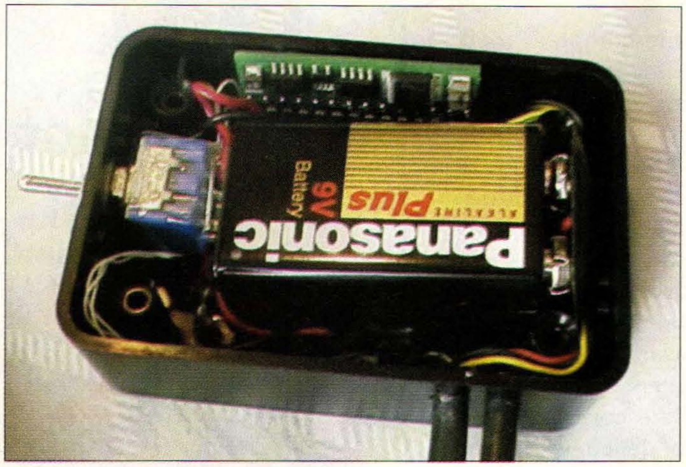


Figure 5: The internals of the computer module, including power switch (left), BASIC Stamp computer (top), and battery (center). Wiring is routed around the perimeter of the module.

greater than 1/16" diameter in bright light. When you're ready for low-light conditions, you will probably need to increase to about 3/16" or so. I recommend drilling two sets of holes as shown. When you want to test in low light, you can select the larger apertures. In bright light, use the smaller ones. To change the aperture configuration, simply remove the cover, rotate it 180 degrees, and re-attach.

Figure 3 shows a sensor module with the cover removed, exposing two photocells. Each photocell is mounted on a small piece of perf board, cut to fit into the slots of the project enclosure. Now is a good time to mention the importance of photocell selection. My initial experiments used a couple of different types. The type I finally decided on is made by a company called Clairex. You'll find the details including the part number and where to buy them listed at the end of the article. You

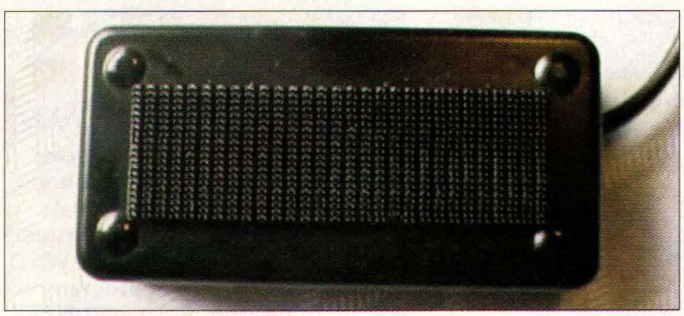


Figure 6: Top of sensor module containing adhesive-backed Velcro.

might be surprised to learn that all photocells are not created equal, even from the same manufacturer and model type. Use a multimeter to measure them in similar lighting conditions, noting the readings. You'll need to select a group of four photocells that are as closely matched as possible. Buy 10 or so to guarantee a good selection.

The remaining part of the system is the computer module. It is the brain of the system, obtaining sensor readings and evaluating the results. Intended for mounting on the dashboard or resting on the passenger seat, the computer module has two visible LED indicators as shown in Figure 4. Each indicator represents the left and right sensor modules. When a sensor detects a lane marking, the indicator illuminates. The computer module is operated by a Parallax BASIC Stamp BS1-IC and a nine-volt battery. Also contained in the module is a piezo buzzer for alarm annunciation. Figure 5 shows the inside of the computer module.

Each sensor module attaches to the computer module with an eight-foot length of four-conductor telephone wire. Drill holes in each project case just large enough for cable entry. Apply a thin layer of Super Glue™ at each opening to secure the cables and to provide strain relief. Wire the system according to the schematic diagram.

To install the sensor modules, use some strips of adhesive-backed Velcro. Apply one part of the Velcro to the underside of the side-view mirror housing. Apply the other part to the top-side of the module as shown in Figure 6. Figure 7 shows the installed sensor module. Route the left sensor cable to the vehicle interior through the crevice where the door panel hinges to the body. Be careful to avoid possible pinch points. Repeat the process for the right side-view mirror. The computer module can be attached to a convenient space on the dashboard using Velcro strips or allowed to rest on the passenger seat.

How it works

Figure 8 shows the schematic diagram of the entire system. The design is based on the concept of light reflectivity. When light hits a surface, a certain amount of it reflects away, while the remaining amount is absorbed by the surface. Different colors have varying levels of reflectivity. Light-colored surfaces have high reflectivity. White, for instance, has high reflectivity. Dark surfaces have low reflectivity. The computer continually takes light readings from each sensor module, comparing each photocell's readings. A significant difference indicates a successful detection.

The diagram in Figure 9 shows the positioning of the photocells, aperture holes, and road markings. As shown, the photocells are slightly offset from the position of the holes. This gives the device two specific fields of view in each sensor module. The computer compares the light intensity from each field. The idea is that one of the fields should "see" lane markings while the other sees the road itself. Since lane markings typically contrast the road surface, the light intensities should differ significantly, resulting in detections.

The test drive

Now that you've constructed the prototype, it's time

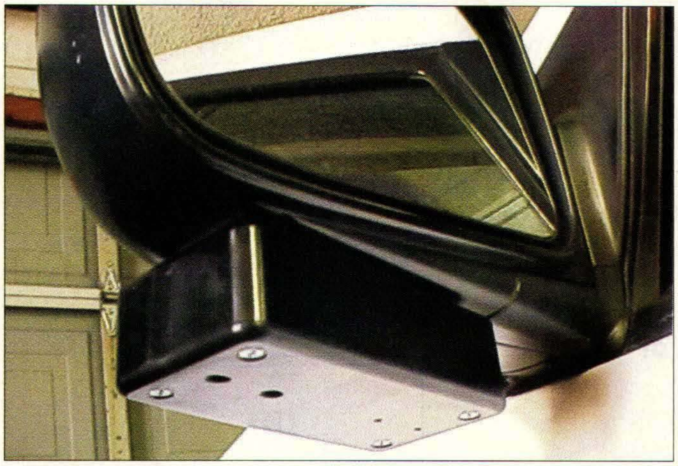


Figure 7: Sensor modules attached to the bottom of the side-view mirror with aperture openings facing down.

for a test drive. First, you'll need to determine the time of day for the test. Generally, you have a couple of choices: low lighting and bright lighting. The selection is important since it determines which set of aperture holes you will use, as described earlier. For bright lighting (e.g., mid-day), use the smaller holes. Too much light will over-expose the sensors and you'll get improper detection. For low lighting (e.g., dawn, dusk), use the larger holes. To change the selection, simply remove the sensor module covers, rotate 180 degrees, and re-attach. Next, make sure the sensor modules have been securely affixed to each side-view mirror and that cabling does not bind or pinch in the door opening.

Now we're ready to roll. Turn the unit on at the toggle switch. Make the appropriate selection for alarm or mute.

Parts List

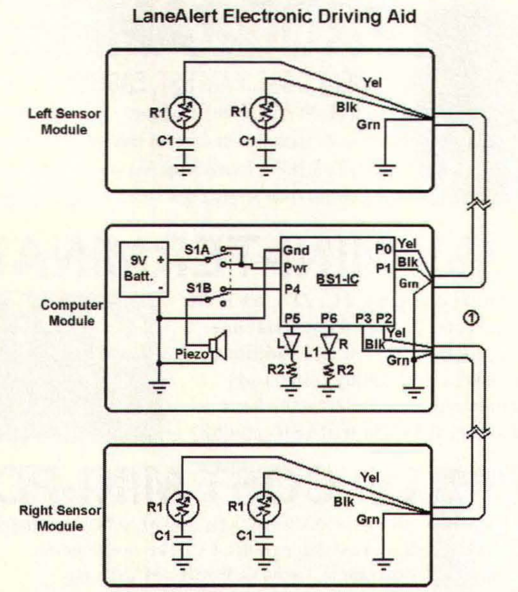
Resistors:
R1 - photocell (Clairex CL5P4L, 690NM)
R2 - 470 ohm (1/4W, 5%)

Capacitors:
C1 - 0.1 uF (ceramic)

Semiconductors:
BASIC Stamp BS1-IC
L1 - LED (yellow)

Misc.:
Telephone wire, four cond., solid, black jacket (20 feet min.)
1 project enclosure (3 x 2 x 1)
2 project enclosures (4 x 2 x 1)
Perf board
S1 - DPDT switch, center off
Piezo buzzer (3.0 - 20VDC, 2.7kHz)
14-pin SIP IC socket
Nine-volt battery
Velcro strips

Notes:
All parts except BS1-IC, 14-pin SIP socket, and photocells available from RadioShack
Photocells available from Mouser Electronics
BS1-IC available from Parallax
14-pin SIP socket (solder-tail) available from Digi-Key



①Telephone wire, 4 cond., solid, black jacket, RadioShack #278-385
R1 - Photocell (Mouser #621-CL5P4L); R2 - 470 ohm
S1 - DPDT toggle switch (center off); C1 - 0.1 uF
L1 - LED (yellow)

Figure 8: Schematic

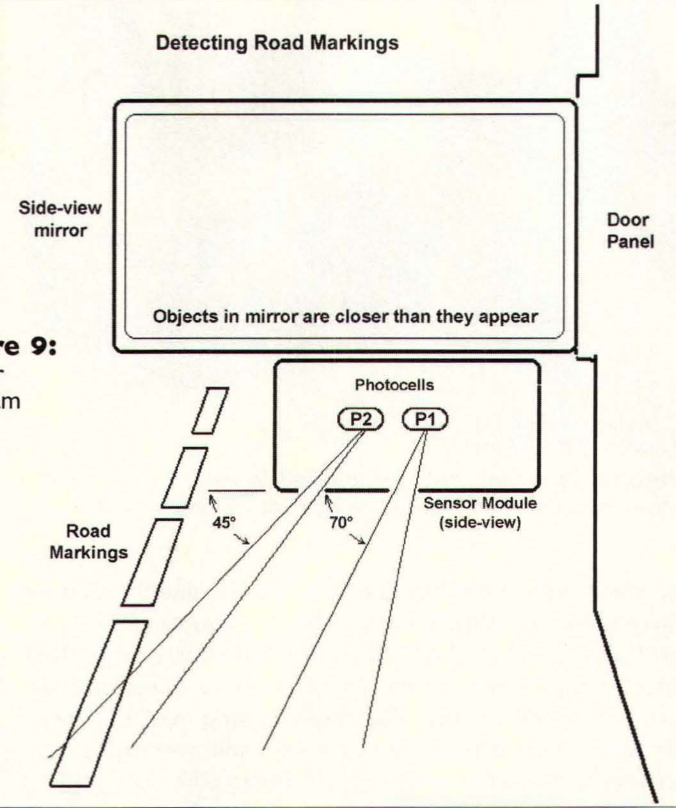


Figure 9: Sensor Diagram

You might want to start out with the alarm enabled. After a while, you should probably mute it to minimize distraction. Instead, just glance at the LEDs from time to time. As each sensor makes a detection, its associated indicator will activate. Remember to keep safety at the forefront of the experiment. Do not take your eyes off the road in a potentially dangerous situation. You don't want to become another statistic. For initial tests, I recommend less-travelled boulevards where speeds are not too great. Try to choose roads with good contrast between the road surface and markings.

A couple of things will trigger sensor detections besides road markings. One of these is shadows, as caused by buildings, power poles, trees, and other vehicles. The other source of detections is road discolorations. During daytime driving, these false triggers are to be expected. If you get good activity from both LEDs, the experiment is a success. If one or both indicators fail to activate, you'll need to return home and do some troubleshooting. The first thing to examine is the sensor module apertures. Make sure they're unobstructed and properly aligned. Next, remove the sensor cover and examine the photocells. They should be slightly tilted in the direction of the aperture. Finally, use a multimeter to ensure you have continuity between sensor and computer modules and that the cables are not damaged.

Code listing

Listing 1 (which is available for download at **www.nutsvolts.com**) shows the BASIC Stamp source code. The code is structured in a continuous loop that runs indefinitely (or until the unit is powered off). Each pass through the loop "reads" each of the two photocells in each sensor module. The values correspond to the amount of light detected by each photocell. The greater the amount of light, the higher the value. The values are compared to determine if a detection has occurred. If the difference is greater than CONTRAST, a detection has occurred. An alarm condition results when no detection has occurred in 50 loop passes (tracked by TCOUNTER). This translates to about three seconds. When this occurs, the piezo buzzer sounds a series of beeps and then silences.

Taking the next step

Remember that LaneAlert is a prototype, a work in progress. It effectively proves the concept of lane detection in sunlit conditions. The obvious next step is to make the appropriate modifications for night driving. Since there is not sufficient lighting, it will need to be improvised somehow, possibly with an onboard illuminator contained in each sensor module.

If you'd like updates on my progress, drop me a note at: **kdelahou@worldnet.att.net**. **NV**

Ken Delahoussaye is a software engineer/consultant with 18-years experience in real-time and embedded applications. He enjoys working with electronic and mechanical devices, prompting him to spend countless hours building all sorts of gadgets. He runs Kadtronix, a small robotics and programming services company in Melbourne, FL.

Build a Poor Man's Metal Detector

This easy-to-build, low-cost circuit is lots of fun for young and old treasure-hunters alike ...

Many of us have seen metal detectors, which are portable electronic devices that contain a search coil that is passed over the ground at an area of interest. When a metallic object is detected, a tone from a speaker or headphones changes pitch, indicating a "find." These sophisticated instruments are used by enthusiasts who like to search for hidden coins and metal objects at the beach and everywhere else. But as you may know, commercially-available metal detectors are not cheap and can cost hundreds of dollars.

You can enjoy the pleasure of hunting for hidden treasures without breaking your budget, simply by constructing the metal detector described here. It's called a "Poor Man's Metal Detector" simply because it can be built for just a few dollars, far less than you might spend on a commercial unit. It employs a very simple beat-frequency circuit that is sensitive enough to locate a coin buried under one inch of earth. This detector is powered by a common nine-volt transistor radio battery, and can be used with a loudspeaker or headphones, as desired.

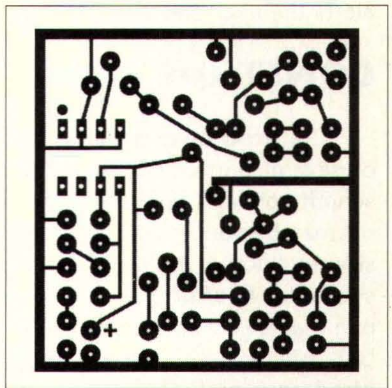


FIGURE 1. Layout of the printed circuit board shown full size as seen from the copper side.

ABOUT THE CIRCUIT

Refer to the schematic diagram. This is a "beat-frequency" circuit in which two oscillators are operating at almost the same frequency, so that an audio signal (difference frequency) can be recovered. A slight variation in the frequency of one oscillator — as the search coil comes within close proximity to a metal object — causes a relatively large change in audio frequency. The circuit contains two almost identical Colpitts oscillator circuits, and an audio power amplifier chip that drives the speaker. The circuit operates by manually adjusting one of the oscillators (Q2) to a frequency that is perhaps 100 or 200 Hz away from that of the other. In this way, the beat frequency can be used to locate metallic objects.

The tuning components of the first oscillator (Q1) are the search coil L1, plus C2 and C3 connected in series. Forward bias to Q1 is provided by R1. This is a classic Colpitts oscillator where the junction of the two capacitors — C2 and C3 — is connected to the emitter. The base and collector of the transistor are returned to the hot and cold side of L1. The circuit thus oscillates at a frequency of about 400 KHz. The circuit of Q2 is similar. In this case, L2 is a fixed inductor of 82 microHenrys, while a varactor (D1) is connected across the tank circuit. Potentiometer R7 is used to provide a variable bias to D1, so that the frequency of the oscillator can be varied both below and above the operating frequency of Q1.

Coupling capacitors C5 and C14 allow a small portion of the energy developed at the emitters of Q1 and Q2 to be

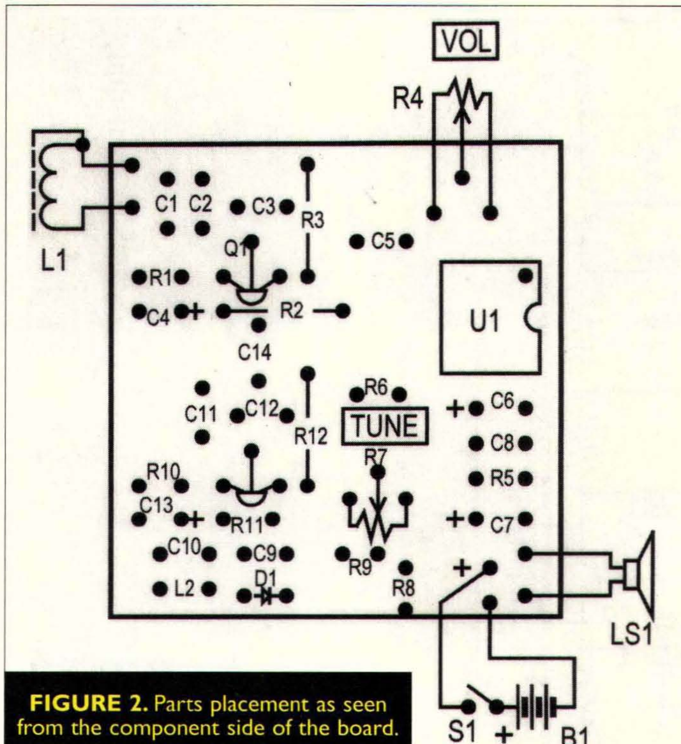


FIGURE 2. Parts placement as seen from the component side of the board.

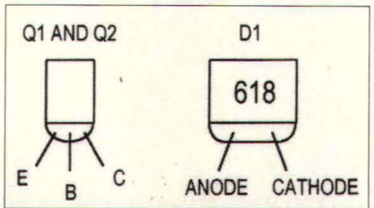


FIGURE 3. Terminal identification of Q1, Q2, and D1.

simultaneously applied to volume control R4. The input circuit of U1 processes the two frequencies to generate a difference, or beat frequency. Since the user sets the difference frequency to within the audio range, it can be heard in the speaker.

During operation of the instrument, the beat frequency is set to a low tone, and the search coil passed over an area of interest. When there is a metallic object within the periphery of the coil, the tone changes frequency. This alerts the user that a metal object has been found.

CONSTRUCTION

Construction of the Poor Man's Metal Detector consists of several parts, which include the printed circuit board, search coil, and final assembly. The printed circuit assembly may be performed first. Refer to Figure 1, which is a full-size rendition of the printed wiring as seen from the copper side of the board. If you do not wish to etch your own board, one may be obtained from the source indicated in the Parts List. Alternatively, the circuit is not critical and may be wired on a perfboard if good construction techniques are employed. Refer to Figure 2 for the location of all parts of the board. It is important that the integrated circuit, transistors, electrolytic capacitors, and diode be placed correctly into the circuit as shown. Any polarized component placed backwards will result in an inoperative circuit, and may cause damage to itself or other parts. Figure 3 illustrates the connections to Q1, Q2, and D1. These parts are polarized and must be properly inserted into the PC board. Be sure to double-check before soldering.

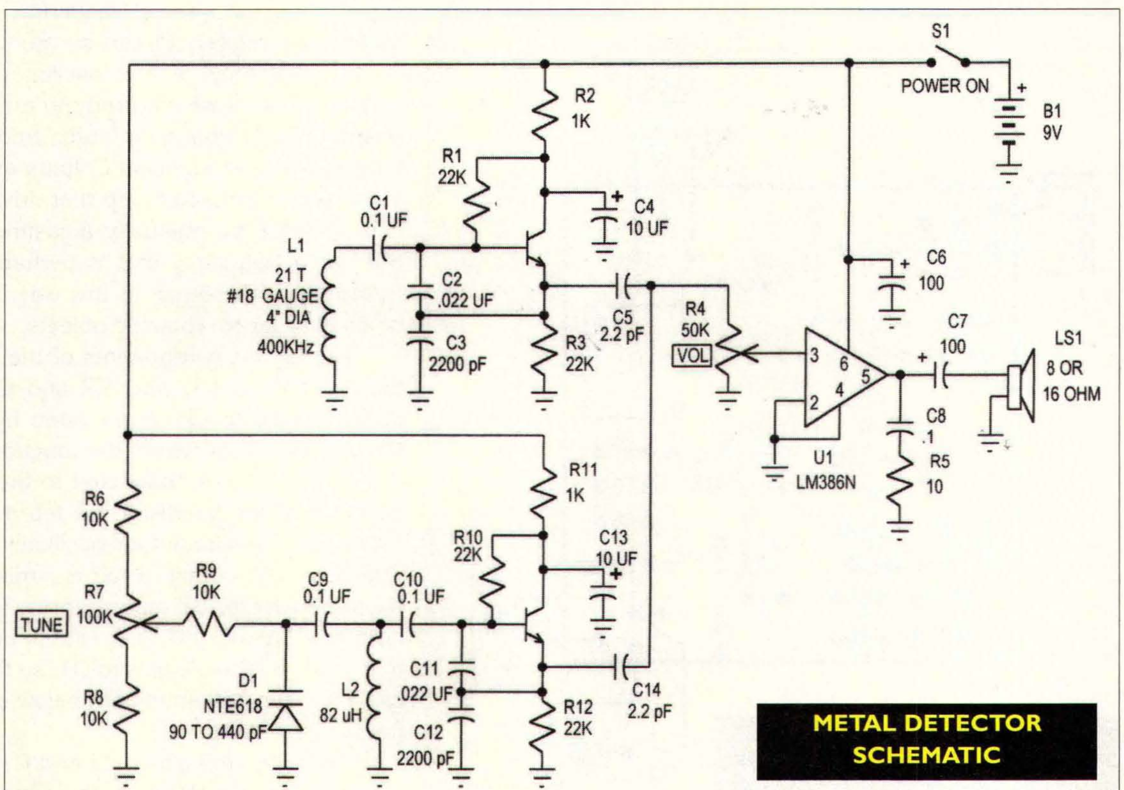
If the 2.2 pF capacitors — C5 and C14 — are difficult to obtain, you can easily fabricate them by taking two 1-1/4 inch long pieces of insulated solid #24 gauge wire and twisting them tightly together. Strip off 1/4 inch of insulation at one end of each wire, and solder into the proper pads of the PC board. Be sure the two wires do not short to each other. Figure 2 also illustrates the connections to L1, S1, battery, tuning control potentiometer, and speaker or headphones. R7 is a panel-mount potentiometer that allows convenience of frequency adjustment during operation of the unit. R4, the volume control, may optionally be placed externally from the board. Use flexible #22 gauge insulated wire for these connections. Using different colors will help avoid miswiring.

When the board has been completed, examine it very carefully for proper component placement. Be sure all solder joints are shiny and smooth, and there are no opens or shorts between closely spaced conductors. It is far easier to correct problems at this stage, rather than later on if you discover that your metal detector does not work. Place the completed board aside while constructing the search coil.

SEARCH COIL

L1, the search coil, consists of several turns of insulated wire wound on a round form. Use 21 turns of #18 gauge enamel wire wound on a four-inch round form such as a plastic container. Hold the turns in place with paper or plastic tape so that the coil remains rigid after it is removed from the form. This will produce a sturdy coil that is easy to handle.

A Faraday shield will be added to the search coil after the preliminary test, which verifies that the inductance of



METAL DETECTOR SCHEMATIC

L1 is correct. The purpose of the shield is to eliminate capacitive effects as the coil is held close to the ground at the area of interest. Such effects could produce false indication of buried metallic objects. When the coil is finished (less the shield), connect it to the printed circuit board as depicted in Figure 2. Use two short pieces of #22 insulated stranded wire to make the connections.

PRELIMINARY TEST

The circuit board must be tested prior to the final assembly of the search coil to ensure that the frequency of operation of each oscillator is correct and the board is totally operational. A nine-volt, well-filtered DC power supply may be used for this test, if desired. Keep the search coil away from all metallic objects when making this test. Set R4 to mid-position. Apply power to the circuit, observing correct polarity. Rotate R7 over its complete range. Normal indication is to be able to hear a varying frequency emanating from the speaker. Adjust R4 for low-volume intensity.

If no zero-beat is obtained, the fixed-frequency oscillator (Q1) may be 10 KHz or more away from the frequency adjustment range of R7. If necessary, refer to the troubleshooting section to verify that both oscillators and the audio amplifier are operating. L1 may require one turn to be removed (or added) to set the fixed frequency oscillator higher or lower.

Check the voltage at the wiper of R7 for which the varying tone goes through zero-beat. Normal indication is between one and five volts. Record this value. Record also the voltages at the wiper that produce a very high-audio frequency on each side of zero beat.

For best resolution of R7, the values of R6 and R8 can optionally be increased to limit the frequency adjustment range. By using the voltages previously recorded that produce a very high-audio frequency on each side of zero-beat, calculate new values for R6 and R8 using Ohm's Law. When new resistor values are installed, the adjustment range of R7 will closely reflect the previously recorded voltages.

TROUBLESHOOTING

If there is no audio response from the speaker, the circuit must be checked to verify that both oscillators are operating close to the correct frequency. An oscilloscope, if available, will be handy.

The best way to troubleshoot a printed circuit board is to first examine it very carefully for incorrect components, solder bridges between closely-spaced conductors, and opens or bad solder joints. All polarized components must be checked for proper placement as indicated in Figures 2 and 3. This procedure will more often than not reveal a defect in the assembly.

Be sure the circuit is powered by at least +8 volts. With component placement verified, check the voltage at the emitter of Q1 and Q2 with a DC voltmeter. Normal indication is about six or seven volts DC. An oscilloscope should indicate a two-volt peak-to-peak AC voltage at the emitter of each transistor. Using the calibrated sweep speed of the scope to check the waveform, the period of each sinewave should be about 2-1/2 microseconds for a frequency of 400 KHz. If the circuit is oscillating, but the frequency is wrong, check L1, C2, and C3 for oscillator Q1. Check L2, C11, and C12 for oscillator Q2.

If the variable frequency of Q2 cannot be set both above and below the frequency of Q1, L1 must have one turn removed or added as necessary. Removing or adding a turn will cause the frequency of Q1 to go higher or lower, respectively. Measure the voltage at the wiper of R7 as it is varied over its range. Normal indication is about 0.75 to 8.75 volts with nine volts powering the circuit. If not, check R6, R7, and R8. If everything looks normal up to this point, but the speaker is silent, check the orientation of U1 and C7. Check C5, C14, and R4. Measure the voltage at pin 6 of U1 to be sure it is at least +8 volts. Check speaker wiring. If necessary, try a new chip and substitute a different speaker.

FINAL ASSEMBLY

A Faraday shield must be placed over the search coil to avoid capacitive effects, which would alter the fixed-oscillator frequency and make it difficult to locate metal objects. This is easily accomplished as follows.

Cut several pieces of household aluminum foil about 1-1/2 inches by six inches long.

Take one piece of the foil. Starting at the point where the pair of leads of L1 come out, wrap it around the coil wires to totally enclose about three or four inches of the periphery. Squeeze the foil tight around the coil.

Take a second piece of foil and wrap it around the coil wires to continue the shield around the periphery of the coil.

Continue with additional pieces of foil as necessary to complete the circle around the coil. There must not be any gaps in the foil covering. When done, there should be a 1/4 inch space between the beginning of the shield and the end. Otherwise, a shorted turn will result.

Take a 30-inch piece of solid bare #24 gauge bus wire, and wrap about two or three turns closely spaced around the shield at one end. Allow at least two inches lead length for connection later.

Carefully solder the turns together to secure the wire.

Wrap the remaining wire around the shield in a spiral manner so that the aluminum foil is held tight around the coil wires. When finished, wrap about two or three turns around the shield, and solder them together as before. Cut off any excess wire.

The bare wire pigtail of the shield should be soldered to the ground side of L1. Connect L1 to the PC board, using two short pieces of insulated flexible wire. Be sure the wire containing the Faraday shield connection goes to circuit common. Check operation of the circuit to verify that it will produce a zero-beat as before.

ENCLOSURE

The PC board, battery, and loudspeaker may be placed in a small enclosure that can be located near the search coil. R7 — the tuning control — should be located where it can easily be adjusted as the metal detector is in use. If

PARTS LIST

B1 — nine-volt alkaline transistor radio battery
C1, C8, C9, C10 — 0.1 uFd 50-volt ceramic disc or monolithic capacitor
C2, C11 — .022 uFd 50-volt polyester or mylar capacitor
C3, C12 — 2,200 pF 50-volt polyester or mylar capacitor
C4, C14 — 10 uFd 25-volt radial electrolytic capacitor
C5, C14 — 2.2 pF 50-volt disc capacitor (see text)
C6, C7 — 100 uFd 25-volt radial electrolytic capacitor
D1 — NTE618 varactor diode
LS1 — 8- or 16-ohm speaker
Q1, Q2 — 2N3904 NPN transistor
R1, R3, R10, R12 — 22K 1/4 watt carbon resistor
R2, R11 — 1K 1/4 watt carbon resistor
R4 — 50K potentiometer, PC or panel mount
R5 — 10 ohm 1/4 watt carbon resistor
R6, R8 — 10K 1/4 watt carbon resistor (see text)
R7 — 100K potentiometer, panel mount
R9 — 10K 1/4 watt carbon resistor
S1 — SPST slide or toggle switch
U1 — LM386N audio amplifier IC

Misc: Battery clip, #18 gauge enamel wire, #24 gauge bus wire, aluminum foil, enclosure, and search handle.

SOURCES OF SUPPLY

Mouser Electronics: **www.mouser.com**; 800-346-6873

Digi-Key: **www.digikey.com**; 800-344-4539

Note: An etched and drilled printed circuit board is available from A. Caristi, 69 White Pond Road, Waldwick, NJ 07463 for $15.00 postpaid.

desired, a connector may be installed to allow the use of headphones. Optionally, R4 may be a panel-mount control mounted to the enclosure to allow field adjustment of volume.

It is up to the builder to provide a suitable handle to which the search coil will be mounted. It is important to have a rigid assembly to avoid frequency shifts when the unit is in use. Do not use any metallic hardware for this assembly.

USING THE DETECTOR

Use a fresh alkaline nine-volt battery. Turn power on and adjust R7 to obtain a low frequency from the speaker. When making this adjustment, be sure the search coil is located away from any metal object. Use as little volume as possible to conserve battery power.

Hold the search coil parallel to the ground at an area of interest. Best results will be obtained if the coil is about 1/2 inch away. Slowly make a sweep motion to cover as much area as desired.

As the coil passes over a buried metal object, the frequency heard in the speaker will either go higher or lower depending upon which side of zero-beat R7 has been adjusted. While moving the coil around the area of the find, you will then be able to determine its exact location.

The detector is capable of finding small objects, such as a dime, that are within one inch of the coil. Larger objects can be found at greater distances.

If the sound emanating from the speaker becomes erratic or weak, replace the battery. **NV**

Build the CF-MOSFET Audio Power Amplifier PART I

An audiophile-quality amplifier of several configurations, many applications, and surprisingly low cost.

Audiophiles have long recognized that there are significant performance shortcomings inherent to the majority of commercially-available audio power amplifiers. Although I do not have room within the constraints of a single article to adequately discuss all (or even most) critical performance parameters relative to human perception, it has been my experience that most commercially-available, moderately-priced audio power amplifiers do fall significantly short of the desirable goal of practical sonic transparency (i.e., reproduction faithful enough so that any sonic coloration being generated in the audio power amplifier is below human perception levels).

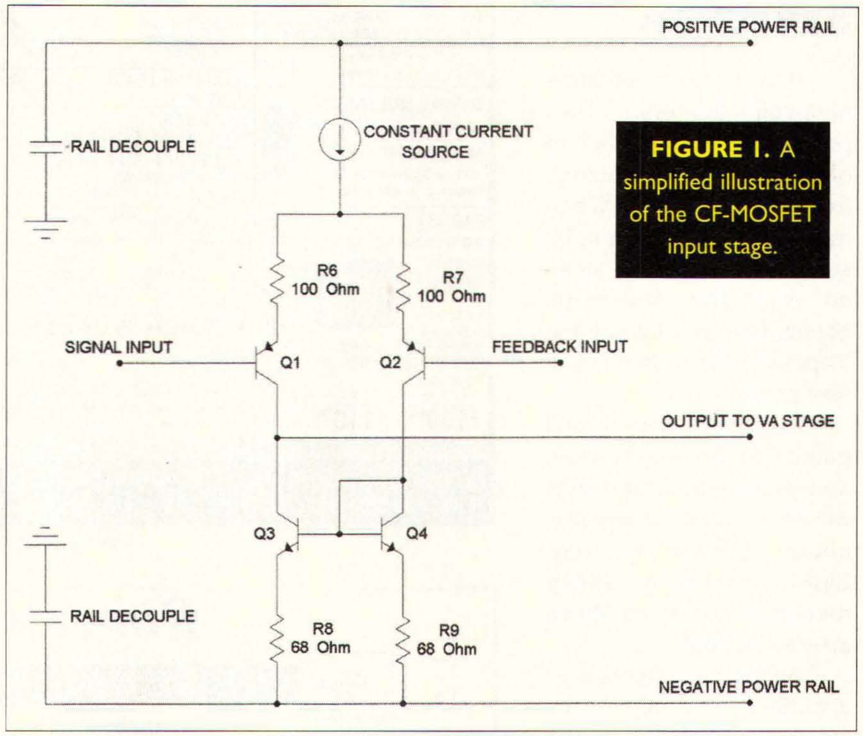


FIGURE 1. A simplified illustration of the CF-MOSFET input stage.

Manufacturers typically measure total harmonic distortion (THD) performance using a 1-KHz fundamental frequency at 0-dB output levels into resistive "dummy" loads. Unfortunately, "real-life" THD performance can climb to very high levels under the conditions of higher frequencies, lower volume levels, and nominally-reactive speaker loading.

Some types of very "nasty" distortion anomalies are created by inadequate slew rates, or as a result of various interactive problems transmitted through the power supply rails (due to the poor power supply rejection ratio, or PSRR, of the amplifier). And I probably don't need to mention the common problems relating to reliability — anyone even mildly involved with audio electronics already knows that audio power amplifiers have a bad reputation of "blowing up."

The quest for excellence in audio reproduction has led the audiophile community down some very exotic and expensive pathways. In today's marketplace, it is common to pay up to $1,500.00 for a 25-watt monaural audio power amplifier, with some solid-state, 100-watt class-A versions selling for as high as $16,000.00! Some of the exotic techniques and expensive methodologies relative to the audiophile marketplace are pure nonsense, being somewhat analogous to the fad of placing holes in the sides of cars back in the 1950s. But a large portion of the progress made in the audio fields during the last two decades is very legitimate, and results in notable performance improvements when properly implemented. Unfortunately, many of the larger equipment manufacturers have not taken advantage of these refinements, due to the R & D costs and the simple fact that they are not targeting the "audiophile marketplace." In addition, many of the improved analog techniques are somewhat obscure, as a result of our modern preoccupation with digital equipment and the general trend away from discrete component engineering.

My goal in writing this article is to present a high-performance, no-compromise audio power amplifier design that can be constructed in the typical home-based hobbyist environment at a reasonable cost. Also, since many of

Tools that will be helpful, but not absolutely necessary:

1. Audio Signal Generator
2. Oscilloscope
3. Good working knowledge of analog circuits

the analog techniques involved seem to be somewhat obscure these days, my intention is to customize this article to be educational, as well as practical.

I am calling this design the "CF-MOSFET amplifier," because it is based on a complementary-feedback output stage design utilizing lateral MOSFETs for output devices (not very original, but I'm an engineer, not a poet). If properly constructed and implemented, the sonic performance of this amplifier will be quite extraordinary, with a reliability factor at least 10 times better than comparable amplifiers incorporating bipolar transistors as output devices.

The applications are many, including any domestic Hi-Fi application, musical instrument amplifiers, medium-power PA systems, multimedia, and commercial audio applications.

Each CF-MOSFET module is capable of providing up to 100-watts RMS or 160-watts RMS (depending on configuration, which is explained later) into typical audio loads, with only 0.004% THD at 1 KHz at maximum output, and only 0.03% THD under worst-case conditions (i.e., about 250 milliwatts at 20 KHz). Roughly speaking, this means that distortion components will always be at least one magnitude below human perception levels regardless of frequency or volume levels, even when driving highly reactive speaker loading. The signal-to-noise ratio (SNR) is better than -100 dB, with noise concerns dwindling into a literal "non-issue" if appropriate construction techniques are used. The bandwidth is from 3 Hz to better than 100 KHz, so transient-related distortion mechanisms can be summarily disregarded. Since L-MOSFETs are absent any secondary-breakdown, thermal runaway, or junction capacitance characteristics (in contrast to bipolar output devices), the amplifier's reliability is increased dramatically.

It was also my goal to remove much of the construction expense, hassle, and complexity from this project. Consequently, I have provided a few options from the typical hobbyist junk box, and I have tried to incorporate components that are inexpensive and readily available. I believe I have accomplished these goals for the most part, the exception being the scarcity and cost of lateral MOSFETs in today's marketplace. However, I have included a good variety of suppliers that carry L-MOSFETs, so there shouldn't be any great difficulties in this regard.

Why Lateral MOSFETs Instead of Bipolar Devices?

The US commercial audio market has been dominated by power amplifiers incorporating bipolar-junction transistor (BJT) output devices for over three decades. In the plus column, BJTs provide excellent linearity, high transconductance, and low cost. On the down side, they suffer from the disadvantages of a positive temperature coefficient (i.e., increasing leakage current with temperature rise), susceptibility to secondary breakdown, beta droop (i.e., a decrease in beta with a corresponding rise in collector current), extreme sensitivity to exact bias requirements, and junction capacitance shortcomings. In high-current, high-frequency applications, BJTs are difficult to protect from secondary-breakdown failures and cross-conduction problems (resulting from stored carriers in the junction capacitances).

Some BJT designs are more susceptible to destruction than others, but even extensive protective circuitry is not always successful in preventing BJT failure under every possible resistive/reactive loading condition. Almost all protection circuits are impotent during power-up and power-down transient conditions, and this situation adds to the overall risk factor. To make matters worse, most protection circuits can produce false-limiting distortion if the speaker load is more than moderately reactive, and this type of distortion is readily perceived and very discordant.

In contrast to BJTs, the high-current temperature coefficient of lateral MOSFETs (L-MOSFETs) is negative, meaning reverse leakage currents decrease with rising temperature. This characteristic automatically eliminates any possi-

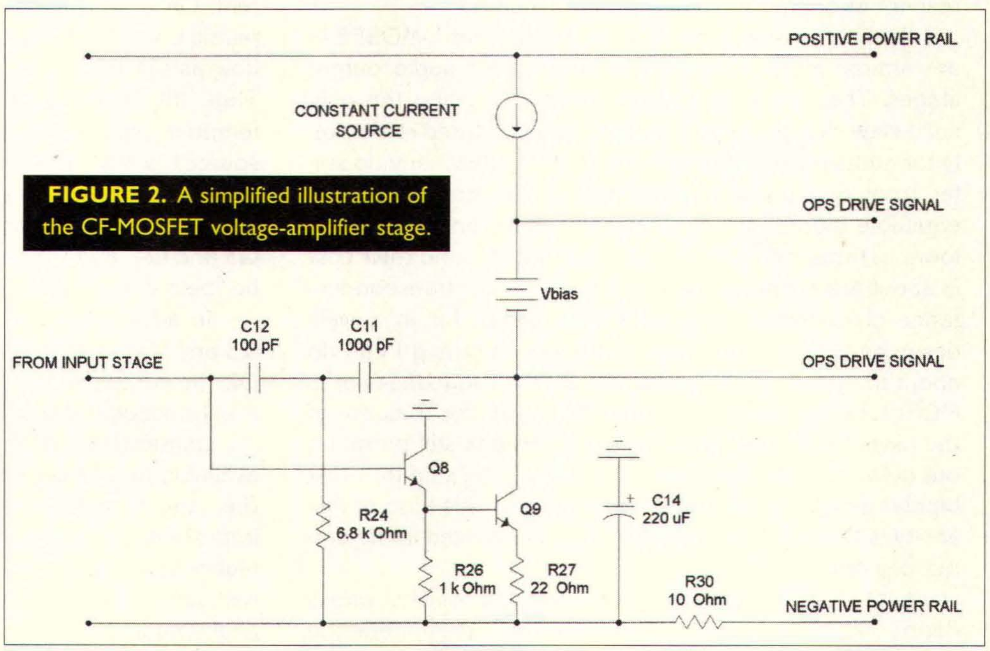


FIGURE 2. A simplified illustration of the CF-MOSFET voltage-amplifier stage.

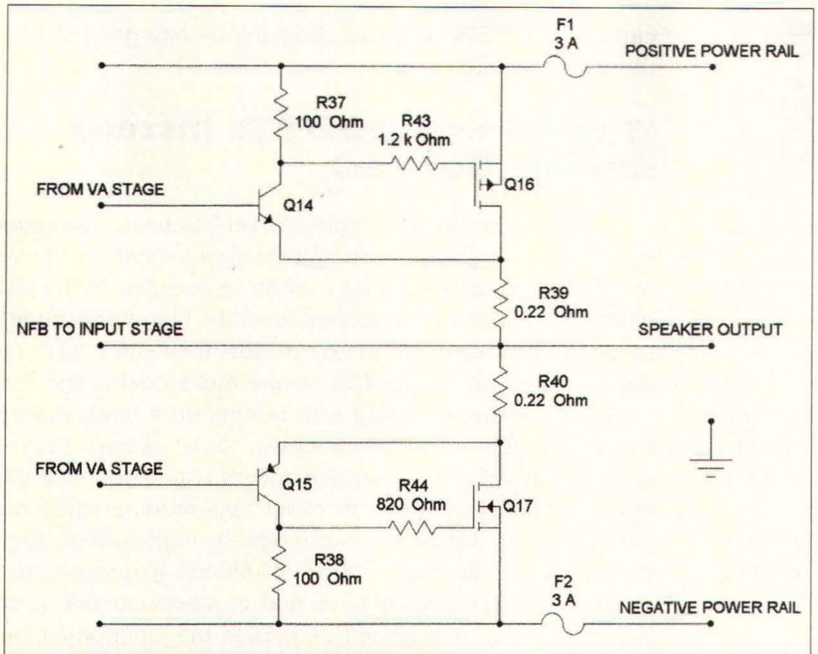


FIGURE 3. A simplified illustration of the CF-MOSFET output stage.

bility of thermal runaway problems. Since enhancement-type L-MOSFETs do not contain any junctions in the high-current channel region, problems relating to secondary breakdown and junction capacitance (resulting in sluggish transition and cross-conduction problems) do not exist. The phenomenon of beta droop is also related to the physics of junction operation, so there is no corresponding "gain droop" mechanism inherent to L-MOSFETs. This characteristic greatly reduces large-signal non-linearities associated with drooping speaker impedances. And finally, when incorporated into class-B complementary output pairs, L-MOSFETs are less sensitive to bias levels in respect to optimum distortion performance.

At first consideration, it would seem that L-MOSFETs are almost ideal devices to implement for audio output stages. They boast the distinctiveness of being the only solid-state devices developed and manufactured exclusively for audio-power applications. Unfortunately, they do suffer from two primary disadvantages in comparison to equitable bipolar devices: they are about one magnitude lower in transconductance (i.e., gain factor) and their cost is about two to three times higher. The lower transconductance characteristic can be compensated for in a well-designed amplifier topology, but there's nothing I can do about the price tag. However, the overall ruggedness of L-MOSFETs is a well-documented fact, with the majority of the classic 70's vintage L-MOSFET designs still pumping out great sound today! The same cannot be said for most bipolar designs. It would seem to me that this kind of reliability is worth the extra $20.00 (or so) invested in the output devices.

L-MOSFETs have been well-received as the prima donna choice for audio output devices throughout the United Kingdom and most of Europe. US manufacturers have, in general, refused to use them because of the cost factor. The advantages of enhancement-type MOSFETs for audio power applications have enticed some manufacturers to incorporate the less-expensive D-MOS families (V-MOS and HEXFET devices) for audio output devices, but this technique represents a poor compromise. The higher Vgs parameters of D-MOS automatically force much higher distortion levels in the final amplifier design when compared to equivalent L-MOSFET or bipolar designs.

The CF-MOSFET amplifier design incorporates an L-MOSFET output stage in conjunction with numerous improvements to the conventional Lin three-stage topology. Collectively, these improvements effectively solve the lower-transconductance compromise associated with L-MOSFETs and provide tangible improvements in several other areas of performance.

Input Stage Fundamentals

Figure 1 illustrates a simplified diagram of the input stage design incorporated into the CF-MOSFET amplifier. A differential input stage (Q1 and Q2) is incorporated. It is not commonly known that optimum linearity in a differential stage is accomplished "only" when the quiescent current levels through the differential transistors are closely balanced. To accomplish such an automatic current balance, transistors Q3 and Q4 are used in a configuration that is commonly called a current mirror. Since the collector-to-base junction of Q4 is shorted, its base-to-emitter voltage (Vbe) will be representative of Q2's collector current. Q4's Vbe is imposed upon Q3, because they are in parallel, which will force Q3 to promote the same current flow as Q4 (assuming Q3 and Q4 are closely matched). Thus, the "total" quiescent current flow through both differential legs (originating from the constant current source) will be evenly split between the two differential legs, and optimum linearity will be achieved. Resistors R8 and R9 help to minimize small Vbe differences between Q3 and Q4, and for best performance, Q3 and Q4 should be "beta matched" to within 10% of each other.

In addition to providing quiescent current balancing, Q3 and Q4 also serve as active collector loads for Q1 and Q2. In comparison to the more common technique of resistor-loading the differential input pair, the active loading characteristic of the current mirror provides twice the available output current to the next stage of the amplifier (i.e., the voltage-amplifier, or VA, stage). This is very important, because one of the more common origins of high-frequency distortion in conventional amplifiers is current-starving of the input stage. Resistors R6 and R7 are degeneration resistors for the differential transistors (Q1 and Q2), providing a significant improvement in overall linearity and temperature stability.

The constant current source of Figure 1 is an active method of supplying a regulated and constant level of operational current to the differential amplifier (Q1 and Q2). In contrast to the common techniques of using a high-value resistor for this purpose, or a zener/resistor combination, a well-designed constant current source provides improved linearity from the differential stage, as well as providing almost total isolation of the differential stage from any variations occurring on the positive power supply rail (an important consideration in establishing the PSRR of the amplifier). Along this same line of thought, the current mirror circuit (Q3 and Q4) also provides some isolation of the differential stage from the negative power supply rail, although it is not as effective at this function as the constant current source.

The input stage's output signal is taken from the collector of Q1 in the form of a current signal, meaning that the input stage is fundamentally a transconductance amplifier. A transconductance amplifier exhibits several advantages over more conventional voltage amplifiers for input stage applications. For one, it relies on the operational physics of transistor operation, rather than the ill-defined value of beta. The input stage transconductance (gm) will be a function of the value of the quiescent current (controlled by the constant current source) and the accuracy of the current balance between the two differential transistors. Transconductance amplifiers also provide improved noise characteristics, and they are less affected by loading variations. As a final note to Figure 1, note that rail decoupling capacitors are installed on both power supply rails. These capacitor networks should be physically located in close proximity to the input stage components for optimum noise and hum reduction.

The Voltage Amplifier Stage

Figure 2 illustrates a simplified form of the voltage amplifier (VA) stage, as incorporated into the CF-MOSFET amplifier design. To take full advantage of the conventional Lin three-stage topology, all of the amplifier's voltage gain should occur in the VA stage. Consequently, a high-gain VA stage will incorporate beta enhancement (i.e., a modified Darlington pair) as provided by Q8 and Q9, in conjunction with active loading, which is provided by the constant current source in the collector leg of Q9. The resulting high beta value working together with the extremely high impedance of the constant current source will result in very high-voltage gain factors.

The current signal input (originating from the input stage) "sees" a moderately low impedance on the base of Q8. Even though a significant impedance exists, this point is commonly referred to as virtual ground, because the important variable is the current signal. R26 and R27 are incorporated to provide temperature stability and degeneration (R27 is also used as a current-sensing resistor for protection purposes, but this will be discussed later). Since the VA stage accepts a current signal input and converts it to a voltage signal output, it is considered a transimpedance amplifier.

The combined gain of the input stage transconductance amplifier together with the VA stage transimpedance amplifier is the product of the input stage transconductance (gm) multiplied by the equivalent beta (of Q8 and Q9) multiplied by the impedance of the VA stage constant current source. Several of these variables are ill-defined, such as the beta of Q8 and Q9, and an accurate impedance evaluation of the constant current source. Fortunately, the exact value of this maximum gain factor — usually referred to as the open-loop gain — is not of great importance. It is only important to insure that the open-loop gain is very high (typically in the realm of 90 to 110 dB) so that high levels of negative feedback can be applied for optimum linearization purposes.

In almost all cases of high-gain, wide bandwidth amplifiers, some form of compensation is necessary. The purpose of compensation in audio power amplifiers is to force the voltage gain to drop with increasing signal frequency, so that unity gain is reached "before" the typical circuitry capacitances cause an output signal phase lag of more than -180 degrees. This is critical for good stability, because excessive phase shifts at the amplifier's output will cause the negative feedback signal to turn into "positive feedback," converting the audio power amplifier into a high-power, high-frequency phase-shift oscillator!

Referring again to Figure 2, the compensation network consists of C11, C12, and R24. In the low-frequency realm of operation, the capacitive reactance of C11 and C12 will cause them to appear to be open, and the voltage gain factor of the VA stage will be at maximum. However, as the signal frequency rises, a significant level of Q9's collector signal will be coupled back to the base of Q8. Since Q9's collector signal is inverted relative to the signal input at the base of Q8, the signal through C11 and C12 is "negative feedback," causing a reduction in voltage gain as frequency is increased. In addition, the operation of the VA stage becomes more "linear" as frequency increases (because increasing negative feedback improves linearity), and the input impedance of the VA stage drops with increasing frequency (which explains one reason that we want the input stage to be a transconductance amplifier, since a current signal is relatively immune to such frequency-dependent impedance variations).

The compensation technique of Figure 2 is commonly

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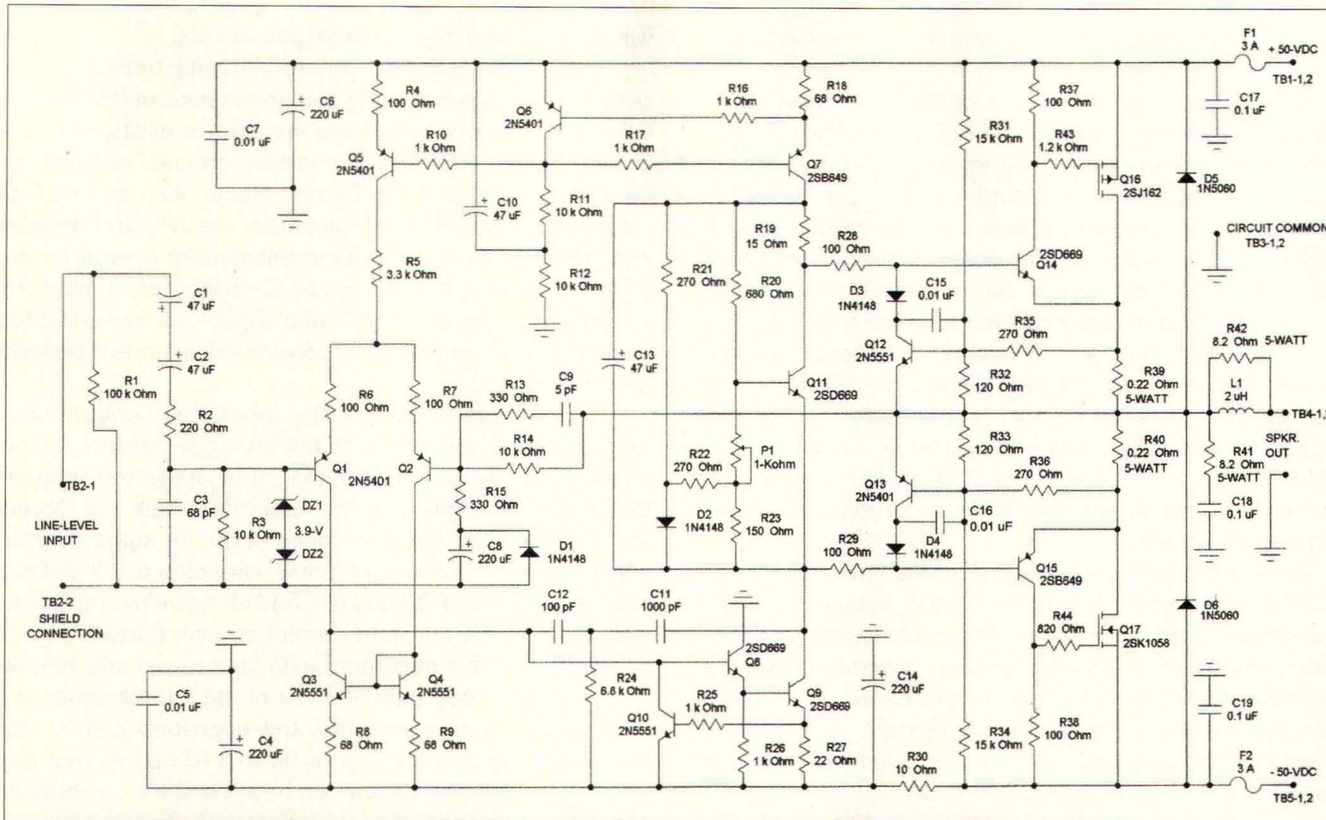

FIGURE 4. Complete schematic of the CF-MOSFET (complementary-feedback L-MOSFET) amplifier.

called two-pole compensation, because it effectively creates two "breakpoints" of the gain rolloff slope. At lower frequencies, the compensation network will promote a -12 dB/octave rolloff of open-loop gain, but as the frequency increases to the unity-gain point, the gain rolloff slope changes to -6 dB/octave. The advantage of two-pole compensation is that it allows a steeper rolloff of the open-loop gain, meaning that the frequency at which the gain rolloff begins can be set higher while still maintaining the same stability factor. Thus, a greater degree of negative feedback (at higher frequencies) can be utilized, improving overall linearity without compromising stability factors.

The battery symbol labeled "Vbias" in Figure 2 is representative of the low-level forward bias network required to bias the class-B output stage into optimum linear operation and reduce crossover distortion. This bias circuit is a simple resistor-diode-transistor network providing an adjustable bias voltage (typically about 1.6-volts DC) from the operational current provided by the constant current source. [The VA stage constant current source is set to provide about 10 milliamps of VA stage quiescent current.] Briefly referring back to Figures 1 and 2, note that a constant current source is utilized to provide "tail current" for the input stage, while another constant current source provides active loading for the VA stage. In both cases, the constant current sources provide almost total isolation from any interference signals that could be superimposed on the positive power supply rail (i.e., signals such as power supply ripple, rectification spikes, crosstalk signals from adjacent amplifier channels, etc.). Unfortunately, the negative power supply rail is not isolated nearly as well.

In the case of the input stage, the current-mirror circuit provides some isolation (as previously stated), and the inherent power supply noise rejection characteristic of the differential stage (Q1 and Q2) adds additional immunity to noise signals. But the VA stage is totally susceptible to undesirable signal injection problems through R27. Thus, it is desirable to improve the power supply rejection ratio (PSRR) with the filter circuit of R30 and C14. These components make up a simple low-pass filter that provides effective filtering of any interference signals riding on the negative power supply rail.

A Hybrid Complementary-Feedback Output Stage

Figure 3 illustrates a simplified version of the CF-MOSFET output stage design. The configuration of pre-driver transistor Q14 and L-MOSFET Q16 forms a complementary-feedback pair (sometimes called a Sziklai pair, after the inventor). Since the pair is made up of two distinct semiconductor families (i.e., BJTs and L-MOSFETs), it is often referred to as a hybrid output design. Likewise, Q15 and Q17 make up an identical, but complementary, output pair.

Q14 is connected in a simple common-emitter configuration, with the input signal voltage applied to the base, and the output signal voltage taken from the collector. The resistance ratio of the collector resistor (R37) to the emitter resistor (R39) establishes the voltage gain at a high value. However, the associated P-channel L-MOSFET (Q16) is configured so that 100% of its amplified drain signal is fed back to the emitter of Q14 as negative feedback, thus reducing the overall voltage gain of the complementary-feedback pair to unity (technically speaking, it will be a little less than unity due to slight efficiency losses of the circuitry). The advantage of such a circuit is that the "local" negative feedback loop inherent to the complementary-feedback pair dramatically improves the overall linearity of the circuit. This technique essentially compensates for the inherent low transconductance value of L-MOSFETs. Of course, the complementary-feedback pair of Q15 and Q17 functions in the identical, but complementary, manner.

The small forward DC bias provided by the Vbias network (in the VA stage) is applied between the bases of Q14 and Q15. The Vbias voltage is adjusted so that a quiescent voltage of approximately 20 millivolts is established between the drain leads of Q16 and Q17 (i.e., the sum of the voltage drops across R39 and R40). This equates to a quiescent bias current of about 40 milliamps through the L-MOSFET output devices, which is an optimum bias level for low-distortion performance. R43 and R44 are "gate resistors," incorporated to suppress parasitic gate oscillations that can occur in L-MOSFETs. The resistance values are different for the P-channel and N-channel devices because the specified gate capacitance differs between the two device polarities (i.e., the 2SJ162 devices are specified at 900 pF, while the 2SK1058 devices are specified at 600 pF).

Finally, note that the speaker output signal is also fed back to the input stage, via the negative feedback (NFB) line. This particular type of NFB is referred to as global negative feedback, because the feedback signal pertains to the functioning of the entire amplifier, rather than being representative of a single, or "local," stage.

Putting It All Together

The complete schematic of the CF-MOSFET amplifier is illustrated in Figure 4. Now that the individual stage functions have been described in some detail, the overall functional description of the amplifier should be a little easier to understand. Beginning at the line-level input, R1 is a type of bleeder resistor, used to provide a discharge path for any external devices that could be providing a signal output through an "open-ended" coupling capacitor. C1 and C2 are tantalum capacitors, configured as a non-polarized coupling capacitor — they should be rated for at least 25 volts.

R2 and C3 form a first-order high-frequency filter for the purpose of attenuating any ultrasonic or RF frequencies that could find their way to the input. R3 sets the input impedance of the power amplifier at 10-Kohm. The back-to-back zener diodes, DZ1 and DZ2, provide over-voltage protection for the differential input transistors (Q1 and Q2).

Capacitors C4, C5, C6, and C7 are power supply decoupling capacitors; the larger aluminum electrolytics (C4 and C6) are not very effective at filtering high frequencies, so ceramic capacitors (C5 and C7) are placed in parallel with them for this purpose.

As previously discussed, Q3, Q4, R8, and R9 comprise the current-mirror circuit. Q1 and Q2 make up the differential input stage, with their associated degeneration resistors, R6 and R7. R5 is installed to drop a portion of the positive power supply voltage that would normally be dropped across Q5, thereby reducing the power dissipation of Q5.

Q5, Q6, Q7, and their associated components make up the two constant current sources required for the input stage and VA stage. Q6, Q7, R18, R11, and R12 form a very conventional constant current source, with the voltage drop across R18 being clamped by the Vbe drop of Q6, and the base reference voltage of Q7 being provided by the collector voltage of Q6. The collector current of Q7 is the constant current source for the VA stage. Note that Q5 simply uses the same reference voltage provided by Q6, which is a technique that eliminates the need for an additional transistor. The collector current of Q5 is the constant current source for the input stage. The decoupling network of R12, R11, and C10 provides very effective ground noise/power supply noise immunity for the reference voltage used by the two constant current sources. Resistors R10, R17, and R16 provide some resistive isolation between the constant current sources, which helps to reduce collateral damage in the event of a component failure.

The Vbias network, which serves to reduce crossover distortion in the output stage, consists of C13, R21, R22, D2, R20, P1, R23, R19, and Q11. If you are familiar with audio circuitry, you will probably recognize this circuit as a variation of the well-known amplified diode circuit. R20, P1, R23, and Q11 are configured so that a failure of P1 will "reduce" the forward bias to the output stage, thus preventing output stage damage if P1 "opens" (a relatively common failure with trimpots). R19 compensates for Vbias voltage variations due to the internal re prime (re') resistance of Q11. C13 smoothes out any AC components existing in the Vbias network. The circuitry of R21, R22, and D2 acts to modify the temperature coefficient response of the Vbias network, causing its corrective action to be more applicable to the complementary-feedback output stage design.

In the case of most L-MOSFET amplifier designs, the Vbias network consists of a simple potentiometer (without any temperature coefficient action), due to the negative temperature coefficient of L-MOSFET devices. Unfortunately, in this design, bipolar transistors are utilized in the complementary-feedback pairs, requiring the need to "track" the temperature of the predriver transistors for an accurate maintenance of the optimum quiescent bias levels. This is the price that must be paid for overcoming the low transconductance characteristic of L-MOSFETs. Therefore, Q11 is physically mounted to the "face" of predriver transistor Q14, and serves to monitor the temperature of Q14 for accurate tracking purposes.

Q8, Q9, R26, and R27 make up the beta-enhanced transistor stage for the VA stage, and compensation is provided by the two-pole compensation network of C11, C12, and R24, as detailed previously. Q10 and R25 form an over-current protection circuit for transistor Q9, which protects Q9 under the following set of circumstances. In the event of a short-circuit condition at the output of the amplifier, Q13 will effectively short the VA output voltage to the output rail. [The connection path running from the common connection point of the emitters of Q12 and Q13, to the output coil, L1, is typically referred to as the output rail.]

The "turning on" of Q13 could draw excessive current through the negative power supply rail (via R27 and Q9), resulting in the destruction of Q9, D4 and Q13. To prevent such circumstances, the emitter current of Q9 is "sensed" by the voltage drop across R27. If this voltage drop exceeds about 0.67 volt (equating to about 30 milliamps), Q10 will turn on and short the drive signal from the input stage to the negative rail, thus limiting the maximum VA current flow to about 30 milliamps. As discussed earlier, C14 and R30 make up a low-pass filter to attenuate any AC interference signals that could be riding on the negative power supply rail.

The output overload and short-circuit protection circuitry is "complementary," just like the output devices. R28, D3, Q12, C15, R31, R32, and R35 make up the single-slope protection circuit that monitors the positive half-cycle outputs applied to the speaker load. Basically, this circuit monitors the voltage drop across R39, and if this voltage level (proportional to the output current) exceeds the safe operating limits of the output devices, transistor Q12 will turn on, and short the drive signal from the VA stage to the output rail. If Q12 turns on, R28 acts as a dropping resistor to improve the signal reduction action of Q12. D3 keeps Q12 from turning on during negative half-cycles (a situation that can happen under rare circumstances). C15 keeps instability (i.e., oscillation) problems from occurring during the activation periods of the protection circuitry. The resistor network of R31, R32, and R35 causes the protection locus (the protection activation area) to have a sloped response, which is more beneficial to the "real-world" needs of the power amplifier than a simple maximum current clamp circuit.

For example, under normal operation, as the instantaneous voltage level of the output rail rises, the protection circuitry allows a higher maximum value of output current, and vice versa. Such a protection response will limit short-circuit currents to relatively low levels (i.e., about three amps), while allowing high peak current values (i.e., over 12 amps) during normal dynamic operation. The protection circuit of R29, D4, C16, Q13, R34, R33, and R36 functions in an identical manner to the aforementioned protection circuit, except that it is incorporated to provide overload and short-circuit protection for the negative half-cycle outputs.

Diodes D5 and D6 are called by a variety of names, such as freewheeling diodes, catching diodes, or transient suppression diodes. Their function is to protect the amplifier's output stage from damage resulting from inductive kickback spikes that can be generated in highly inductive speaker loads. C17 and C19 are decoupling capacitors, physically located close to the rail fuses. They help to attenuate any AC components (i.e., interference signals) originating in the power supply. F1 and F2 are incorporated to protect the amplifier, as well as the speaker load in the event of a component failure. They are GMA-type, three-amp, fast-acting units.

Note that a portion of the output rail signal is fed back to the base of Q2 (i.e., the inverting input of the differential input stage) through the R13, C9, R14, R15, C8, and D1 network. This is the global negative feedback loop. R14 must be the same resistance value as R3 to minimize DC offset errors at the amplifier's output. The resistance ratio of R14 and R15 determines the voltage gain of the overall amplifier (commonly called the closed-loop gain). In this case, the sum of the two resistors (R14 + R15) divided by R15, comes out to a closed-loop voltage gain of 31.3 (+29.9-dB).

Thus, a one-volt RMS input signal would be amplified to an output RMS voltage level of 31.3 volts, which equates to an "ideal" RMS output power level of 122 watts into a typical eight-ohm load. Of course, there will be some minor losses due to power supply droop and output stage inefficiencies, so the "actual" output power delivered to the speaker load would be a little less than the calculated 122-watt level. The resistance value of R15 can be modified for more or less gain (which determines the input sensitivity of the amplifier) according to your needs and applications.

Continuing to refer to the global negative feedback loop, there are actually "three" gain mechanisms involved with the complete loop operation. The first of these is the low-frequency signal-voltage gain, as detailed in the previous paragraph. The second is the R13/C9 phase advance network. This is a type of high-pass filter, which allows very high frequencies to pass through C9, with these high-frequencies affected by the modified gain-determining ratio of R13 and R15 (Ae = 0.5). The phase advance network provides some stability improvement (since high-frequency, phase-lagging gains are reduced), and also helps to linearize high-frequency signals in the audio bandwidth by increasing their negative feedback level.

The third gain mechanism relates to the "DC gain" of the loop, and functions to decrease any undesirable DC voltage offsets. Capacitor C8 presents a very high impedance to any DC levels, so it essentially provides a 100% negative feedback factor to any DC offsets appearing at the amplifier's output. The typical output offset errors of this amplifier design is approximately 20 millivolts. In the event of an output stage component error, diode D1 protects any high levels of reverse-polarity voltage that could build up and destroy capacitor C8.

The functions of the global negative feedback loop are very critical to the linear operation and stability of the overall amplifier design. However, it is obvious by examining the Figure 4 schematic that the external speaker load will have a profound effect on the loop operation, since the speaker load is almost directly connected to the loop signal, which originates from the output rail. Consequently, it is desirable to provide some signal conditioning and isolation between the output rail and the external speaker load. C18 and R41 make up a Zobel network, which primarily minimizes the effects of whatever inductive characteristics may exist in speaker load. L1 provides a counter-effect action to any capacitive effects that may exist in the speaker load, with R42 serving as its associated damping resistor (i.e., to dampen out high-frequency resonant oscillations that could occur between the output coil and the unknown value of speaker load capacitance).

In Part 2 of this article, the physical construction of the CF-MOSFET amplifiers will be detailed, along with construction options, PC board artwork, suitable power supplies, adjustment procedures, and junkbox options. **NV**

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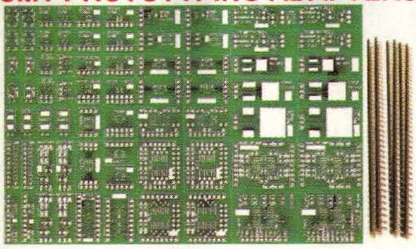

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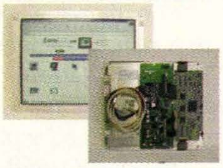

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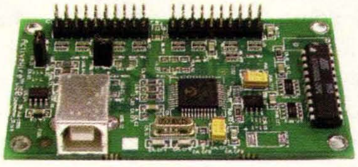

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The Fighting Robots Are Back!

The fighting robot craze is returning to Southern California on **February 8th, 2003** when Steel Conflict — robots with attitude — presents the Robot Fighting League's South West Championship!

The sport of robotic combat is growing exponentially nationwide and the Robot Fighting League is where they compete. According to event promoter Steve Brown — founder of Steel Conflict and himself a builder of three successful combat robots — "This is an exciting time in the sport. There are over 160 robots converging on the Fairplex for the division championship and they all have the same objective, destroy the opponent and win the division title!"

The Robot Fighting League (RFL) is a conglomerate of fighting robot organizations from all over the US. Combined, they hold over 50 tournaments a year. The RFL South West Division is represented by Robojoust in Las Vegas, NV, BotBash in Tempe, AZ, and Steel Conflict in Southern California. The best robots from these three regional tournaments will be fighting it out in a steel arena for their shot at the division title and a trip to the RFL Triangle Series National Championship at the Minnesota State Fair.

The RFL South West Championship — hosted by Steel Conflict — will be held February 8th and 9th at the Fairplex in Pomona, CA. Steel Conflict is expecting over 6,000 spectators. Tickets are on sale now and can be purchased from the Steel Conflict website: **www.steelconflict.com**. For more information on the Robot Fighting League, visit **www.botleague.com**. "The world will never be the same after this one," Brown says.

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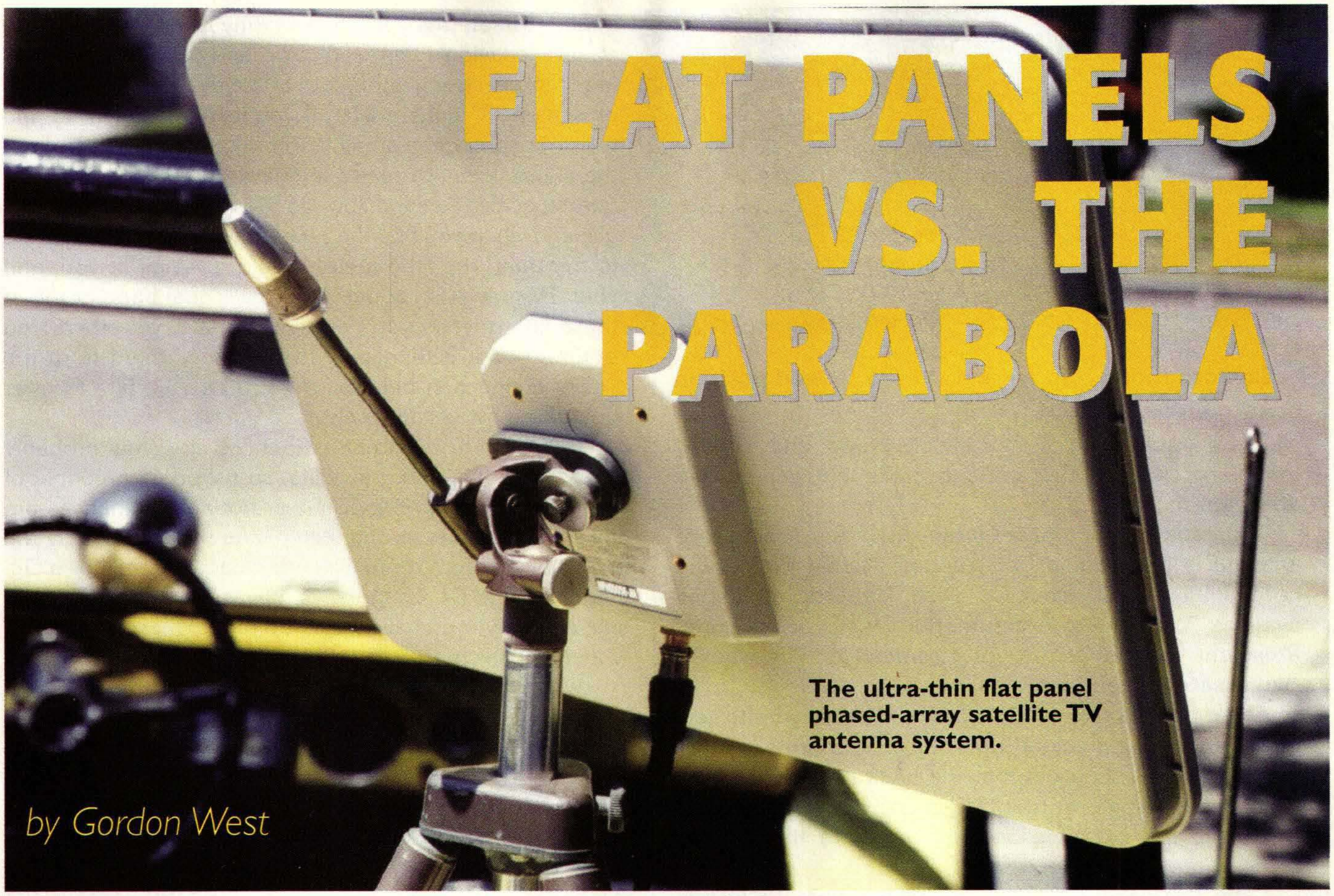


The ultra-thin flat panel phased-array satellite TV antenna system.

by Gordon West

Pulling in 12 GHz signals from Direct Broadcast Satellite (DBS) television satellites out 22,500 miles is best accomplished with the traditional 18-inch parabolic reflector and its associated LNB (low noise block) down converter.

The geostationary satellites broadcasting Dish™ and DirecTV™ programming offer a good balance of power output to the modest gain of an 18-inch dish for nearly 100 percent signal reliability during good weather conditions. But during periods of intense rain activity or wet snow conditions, 12 GHz signals may be dramatically attenuated by the suspended water molecules, and freeze-frame or picture blackout occurs. But just sit tight — generally, the localized storm cell will pass through, and magically direct broadcast satellite television reception resumes.

Nothing beats a good dish.

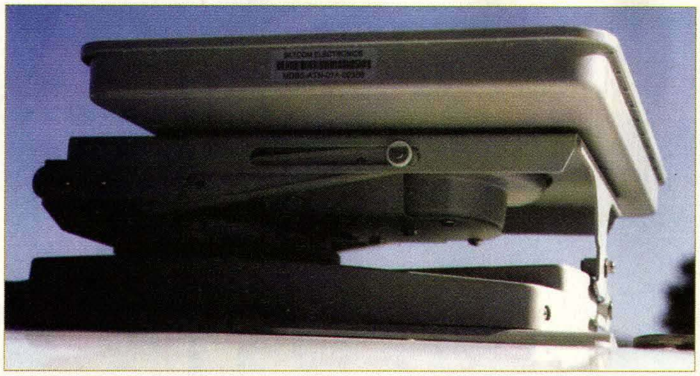
In the recreational vehicle (RV) industry, the white dome you see for direct broadcast satellite reception covers up a modified form of a parabolic reflector that stays locked onto the selected satellite even with the RV in motion.

The KVH (**www.kvh.com**) TrackVision LM — plus others — is a good example of parabola antenna efficiency inside a relatively low-profile, 18-inch high dome. It will track the satellite better than 30 degrees per second, operating off of 12-volts DC at three amps. It has an elevation range of 15 degrees to 75 degrees; and as you are RVing down the road, the antenna control unit from KVH generates a conical scanning function to maintain peak signal strength to the receiver and to update the satellite's position. When conical scan tracking is active, the antenna moves continually with a circular motion to sweep across the satellite's peak signal. The signal strength is then fed back to the control circuits to keep coming back to the direction of the strongest signal. With the KVH antenna — once you park — you can turn off the motorized tracking to avoid unnecessary current consumption. The antenna will continue to receive the satellite TV signals, and relay them to the receiver.

Flat-panel technology is becoming an important factor as we go higher up the microwave spectrum to pull in satellite signals.

But not everyone in smaller RVs needs an antenna that is actively tracking the incoming microwave TV signals. The smaller RV may opt for a portable dish that gets deployed on a tripod when they get to their favorite campsite, or maybe a dish on the roof that will "nest" as they travel down the road. While the dish is the unqualified winner of best incoming signal strength capabilities, direct broadcast signals from the geostationary television satellites have enough "headroom" that an antenna design with slightly less gain than the 18-inch dish will still achieve rock-solid reception with a clear shot at the sky, and reasonably good reception during inclement weather.

Enter phased-array technology — microwave receiving



SatCom motorized antenna in the stowed position.

elements etched on a flat circuit board and phased to obtain close to the same approximate gain as an 18-inch dish.

"Our flat-panel, phased-array, kU band, microwave antenna is revolutionary because of its thin profile and compatibility with DirecTV, Dish Network, and Bell Express Vu System," comments Dr. H. H. Chung, President of SatComm Electronics in Poway, CA (**www.satcomweb.com**).

"Our panel is circular polarized and is etched with several hundred individual microwave elements," adds Chung, also pointing out that the back of the flat panel also contains single- or twin-LNB outputs, getting their DC power via the coax feed coming up from the satellite receiver.

The flat panel we tested measured only 16 inches wide, 12 inches high, and catch this — only two inches deep. It weighed in under five pounds, and was thin enough to store under an RV mattress when not in use.

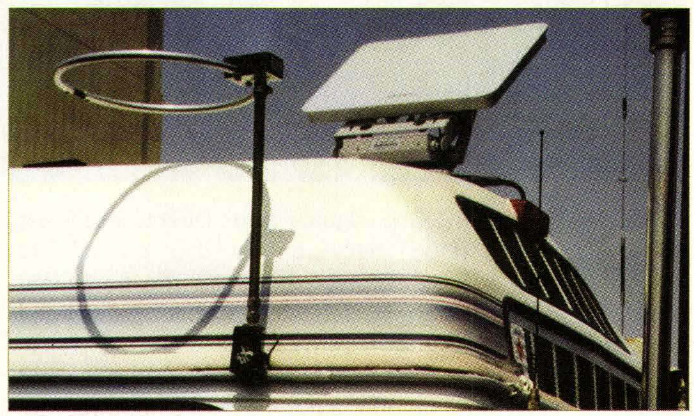
During our tests, we compared the SatComm flat panel to a traditional 18-inch dish from as far south as the Mexican border and north to Yellowstone, WY. The flat panel took the same kind of precise aiming as the 18-inch dish. While compasses are good, we found the easiest way to aim the dish was looking for a peak in signal strength with the coax cable series signal strength meter in line. These analog meters sell for around $40.00 and anyone who regularly moves their satellite antenna system around and in an RV uses one.

Start by setting up the dish or flat panel to the approximate position that you see everyone around you looking at, give it a wiggle here and there, and see if you can pop-in reception strong enough to refine the pointing with the on-screen TV signal meter. If you just can't seem to find the right spot, get a small 75-ohm jumper cable, and put the signal strength meter in line and twist the knob for quarter-scale reading. Now, do the dish or flat panel wiggle; and when you find the "sweet spot," the needle jumps to the right, the little meter mail also sings at you, and your TV may or may not show the signal bars. Some of these little meters you can leave in line, yet others you optimize your setting, and then remove them from the series connection because they rob a little bit of power going to the satellite receiver.

The active tracking KVH antenna is small, portable, and easy to install.

Still no TV reception? Chances are you probably locked onto the wrong satellite, so try again a couple of degrees to the left of your initial "hot spot." Chances are you'll spot another strong signal, and this is probably the one you want! SatComm even manufactures their own digital meter that Dr. Chung says may many times be left in line, and they even have a step-up model that will positively identify which TV satellite you have locked into.

When we tested the flat panel versus the dish with



The SatCom satellite TV antenna during our testing.

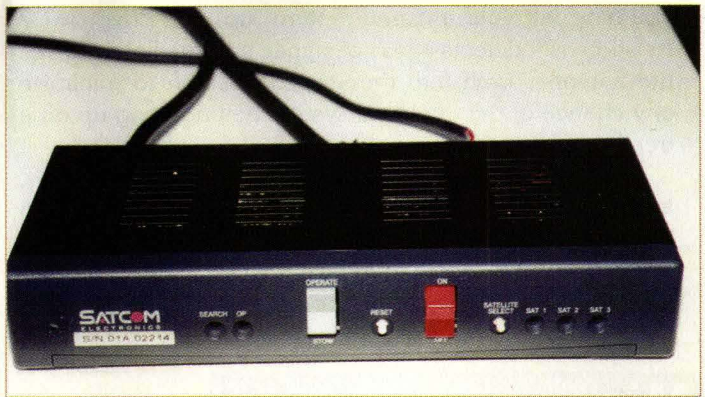
trees all around us, we found that both the panel and the dish needed an unobstructed view of the sky through heavy foliage. But just a few tree branches or leaves generally did not create problems except for a few freeze-ups.

But when the heavy clouds and approaching rain squall began to form in between our RV and the distant TV satellites, the dish would hold on longer before freeze-frame. The dish had more gain to overcome the path loss due to heavy moisture. But as soon as the heavy squall passed overhead, both the dish and the flat panel would almost simultaneously regain enough signal strength to provide reception to the satellite receiver.

But probably the biggest advantage of the flat panel over the dish was when we were ready to move on and store the equipment. The panel slides out of the way. The bulky dish with its pivoting LNB arm always seems too big to go completely out of the way. It's just a little too large to store in one locker, and a little too deep to put in another. If you have a small mobile home or you plan to go tent camping, the flat panel is a delight!

"Believe it or not, there is an advantage to slightly less gain with our flat panel," comments Dr. Chung. "Alignment to the satellite is not as critical as with the dish, and if the flat panel is temporarily installed on, let's say, an RV bicycle rack, movement within the RV won't unlock the picture that may sometimes occur with the conventional dish."

Our next test was to take the flat panel and work it with the SatComm automatic acquisition, motorized, mobile antenna base. The flat panel mounts quickly to the motorized base unit, and now stands only 5.6 inches tall in the stowed position. The motorized mobile base unit is indeed a heavyweight — 14 pounds — but a lot of this weight is designed for safety as the unit on a motor home will be exposed to high winds and an occasional brush with tree branches.



The small control panel mounts by the TV set.

"Our flat panel motorized, automatic acquisition, satellite antenna system does more than just pull in direct broadcast television reception," comments Dr. Chung. "For RVers on the move, our antenna and accessories are designed with broadband satellite communications in mind, taking advantage of high-speed Internet downloading," he adds, speaking of the possibilities with the Canadian satellite system.

This capability could allow you to electronically steer the antenna motor system to an alternate satellite to access your mobile Internet account, and let a Canadian or US geostationary satellite beam down mountains of email in a fraction of the time it takes to collect it via terrestrial wires or wireless connections. The SatComm automatic acquisition, motorized antenna unit will commence a sky search and lock into as many as 12 different satellites for instant recall with the small controller inside your motor home.

"Emerging technologies will bring unprecedented efficiency to broadband data compression for audio, video, and multimedia, and our flat panels will facilitate wireless satellite communications to and from even micro devices," adds Dr. Chung, giving us a sneak preview of what lies ahead beyond simple TV viewing from an ostensibly TV satellite antenna.

In the generic search mode — a default setting — our test unit took less than 60 seconds to acquire the first TV satellite, and then a few seconds later picked up other satellites with sufficient incoming signal strengths. It was easy to choose which satellite we wanted to lock onto by just pushing one of the six buttons. A secondary button brings in six additional satellite position selections.

The face of the remote controller has red light-emitting diodes to constantly show you the status of the system. Once the status shows "locked" and you are beginning to pull in great television satellite reception, you can shut down the controller to conserve current that would otherwise be going into the motor drive system. Now the automatic acquisition drive assembly becomes passive, and you receive the incoming signals from the poised flat panel array just like you did with the flat panel all by itself on a little tripod outside your coach.


Tripod mounting of the flat panel SatCom TV antenna.

But what happens if you forget that

you have left your antenna system "up" and drive away? As soon as it detects a loss of signal, it immediately drives the antenna down into the stowed position to minimize any chance of the deployed system getting hung up on a tree branch.

This is a safety feature which we tested several times, and it works absolutely as advertised. Only once during a big cloud burst did it become a problem — it went into an emergency nest even though we knew it was just a passing rain shower that would soon go away. I suppose for long-term use at an always fixed location, you could wire around the automatic acquisition feature and run your cable directly to the flat panel, keeping the motorized assembly frozen at a specific position. But this does away with the safety feature of automatic nesting, so we didn't try this trick.

So what does all this stuff cost? If you get just a simple dish and LNB, along with a tripod, probably under a couple hundred bucks. Compare this to the flat panel with single LNB at $249.00, with a tripod mount screw receiver already in place. The flat panel with twin LNB is $299.00, and the digital satellite seeker meter around $70.00. The satellite specific meter is $120.00.

For a full-blown, automatic-acquisition KVH or other large dome system, expect to spend $3,000.00 (as a minimum) on up. But for the SatComm automatic-acquisition including the phased-array, flat-panel antenna, including twin LNB output, you pay a little over $1,200.00.

The motorized unit comes all cabled up for "plug and play" and all you need to do is just add 12 volts and mount the unit up on the roof, or plan to set it up on a nearby bench. It is a fine piece of motorized electronics, so I wouldn't necessarily leave it on the bench overnight.

As more and more services become geostationary satellites born to match up with your computer, I see flat-panel technology becoming an important factor to minimize space and to facilitate your own satellite system that can actually fit in a backpack.

As we go higher up the microwave spectrum, be assured that phased-array technology with flat panels may be the chosen way to pull in these incoming satellite signals. **NV**

Home Automation Via the Web

by Michael Gardi

Add a web interface to your X10-based home control system.

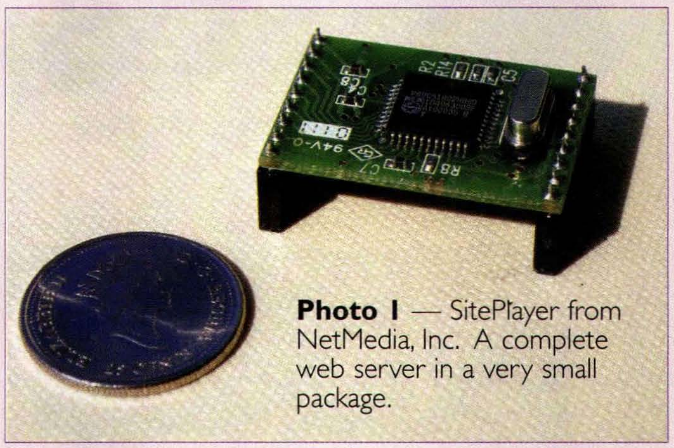


Photo 1 — SitePlayer from NetMedia, Inc. A complete web server in a very small package.

In this article, I will describe how I added a web interface to my X10-based home control system. I'd like to say that this project arose out of a pressing need to provide external control for some critical operational aspect of my home, but I'd be lying. Truth of the matter is, I undertook this project because I thought it would be fun to do. It also brought together in a very nice way some of my recent interests: PIC programming, home automation, and web interfacing.

Talking to Your Home

Home automation hardware has been around for years. X10-based systems are by far the most popular today. The term X10 refers to a communications protocol that allows devices to talk to each other via the existing 110V electrical wiring in the home. No costly rewiring is necessary. In addition to this, wireless radio frequency transceiver units are available to extend the reach of X10 beyond the "outlet."Each device that participates in an X10 "network" is assigned an address (usually via external switches on the device itself). Up to 256 different addresses are available by combining "house codes" (the letters A-P) with "device codes" (the numbers 1-16). If you want more than one device to respond to the same signal, simply set them to the same addresses. One of the beauties of this system is that all X10 compatible products can be freely mixed and matched. Quite a number of vendors offer home control products based on the X10 protocol. A list of X10 manufacturers can be found in the "More Information" sidebar.

More Control With the CM11A

A powerful recent addition to the X10 arsenal is the home automation controller: a software programmable X10 transmitter device (some have the ability to receive status information from X10 devices, as well). Typically, these units connect to a PC via the serial or parallel port, and come with Windows-based software that enables you to control your home with the click of a mouse. There are a number of controllers available, but the one that I used for this project is the CM11A from X10 (www.x10.com).

A CM11A plugs into any outlet (preferably one close to your PC) and comes with a cable that connects the CM11A to a serial port on your PC. The PC communicates to the CM11A using an RS-232 based protocol at 4800 baud (eight bits, no parity, one stop bit). The CM11A handles the X10 protocol to your devices. We'll explore this in more detail a bit later.

Table 1

House Code	Device Code	Binary Value
A	1	0110
B	2	1110
C	3	0010
D	4	1010
E	5	0001
F	6	1001
G	7	0101
H	8	1101
I	9	0111
J	10	1111
K	11	0011
L	12	1011
M	13	0000
N	14	1000
O	15	0100
P	16	1100

Table 2

Function	Binary Value
All Units Off	0000
All Lights On	0001
On	0010
Off	0011
Dim	0100
Bright	0101
All Lights Off	0110
Extended Code	0111
Hail Request	1000
Hail Acknowledge	1001
Pre-set Dim (1)	1010
Pre-set Dim (2)	1011
Extended Data Transfer	1100
Status On	1101
Status Off	1110
Status Request	1111

Introducing a Web Interface

The ActiveHome software that ships with the CM11A is very good. It provides a clean visual interface to the devices under control.

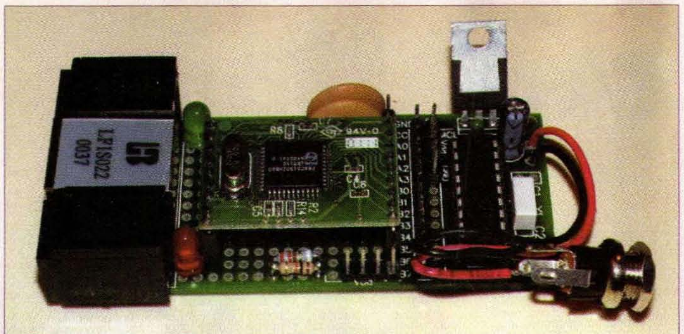


Photo 2 — Top view. All components fit nicely onto the PICProto18 board.

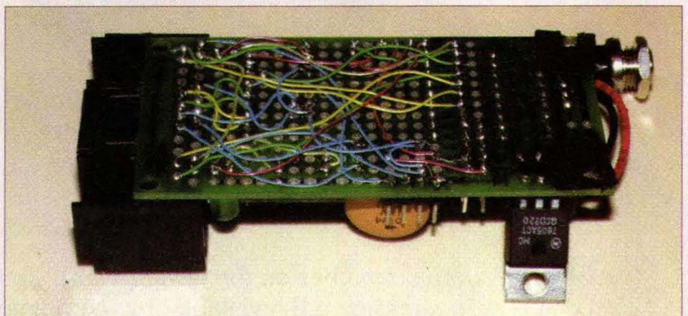


Photo 3 — Bottom view. Point-to-point wiring is a bit tight, but not too bad.

The only problem is that you have to physically be at the PC to which the CM11A is attached in order to use it. If you could somehow connect the CM11A to a web server, then you could control your household devices from any browser that has access to that server.

While your favorite web site is probably running on expensive high-end hardware for light use, web server software will run comfortably on a low-end PC. So one way to add a web interface to the CM11A would be to run a web server package on the PC that it is attached to. This can be made to work, but you would have to leave your PC on all the time in order to access the CM11A.

How Small Can You Go

Enter the SitePlayer by NetMedia, "the world's smallest Ethernet web server." This one-inch square device is a complete web server solution, and forms the heart of this project. (See Photo 1.)

SitePlayer handles all of the web protocols required to deliver web pages over the Internet. SitePlayer has about 48K of flash memory available for your web pages. Standard web authoring tools can be used to make the pages. Web pages are downloaded to the SitePlayer through the Ethernet connection. You can obtain the PC-based software necessary to bundle and download your pages from the SitePlayer web site (www.siteplayer.com).

SitePlayer has a powerful object system called SiteObjects.™ This feature maps special fields on stored web pages to internal SitePlayer variables or to external events. The key SiteObjects feature used in this project is the ability to map a link on a web page to the built-in serial communications port. In other words, when you click on this special link, a sequence of characters (of your choosing) will be transmitted from SitePlayer's serial port.

Composing a Command

So, given that the CM11A can receive commands via RS-232 and the SitePlayer can be set up to serially transmit command strings at the click of a mouse button, what has to be sent? A "standard" transmission to the CM11A refers to the communication of a house code and device code combination, or the transmission of a function code. The binary format for house and device codes can be seen in Table 1. Function codes are listed in Table 2.

A standard command consists of two bytes, a "header" and a "code" byte. The header byte is composed as follows:

Header:

Bit-7 Bit-6 Bit-5 Bit-4 Bit-3	Bit-2	Bit-1	Bit-0
Number of Dims (values 0 to 22) Dim/Brighten by ((Dims / 22) * 100)%	Always 1	0=Address 1=Function	Always 0

If Bit-1of the header is set to 0, the address code byte that follows will look like:

More Information

This article covers quite a number of diverse topics: X10 home automation, PIC programming, web protocols, etc. I have tried to touch on enough of the key parts of each topic in order to describe how my web-based X10 device works. For a better understanding of the topics covered, please check out the following links.

X-10 Home Automation

A couple of good general sites:
www.homeautomationforum.com/
www.geocities.com/ido_bartana/

Vendors:
www.x10.com/
www.marrickltd.com/
www.leviton.com/
www.act-solutions.com/

CM11A Communications Protocol Documentation:
http://software.x10.com/pub/manuals/cm11a_protocol.txt

SitePlayer

www.siteplayer.com
http://fargo.itp.tsoa.nyu.edu/~tigoe/pcomp/siteplayer.shtml
http://mypage.bluewin.ch/a-z/laforge.brenles/SitePlayer/index.html

PIC Microcontroller

www.microchip.com
www.piclist.com/techref/microchip/davidtait/picprog.html

Address:

Bit-7 Bit-6 Bit-5 Bit-4	Bit-3 Bit-2 Bit-1 Bit-0
House Code	Device Code

If Bit-1 of the headers is set to 1, then a function code will follow with the format:

Function:

Bit-7 Bit-6 Bit-5 Bit-4	Bit-3 Bit-2 Bit-1 Bit-0
House Code	Function

You not only have to know what to send to the CM11A, but you have to know how to send it. The CM11A uses an asynchronous handshaking protocol. A typical command sequence might look something like Table 3. This sequence will address lamp modules A1 and A2, then dim them by 72%. The checksum is simply the sum of the command bytes send to the CM11A module 256. The CM11A also supports an "extended" command similar to what has been described here, but four bytes in length. A link to the complete CM11A Interface Communication Protocol can be found in the "More Information" sidebar.

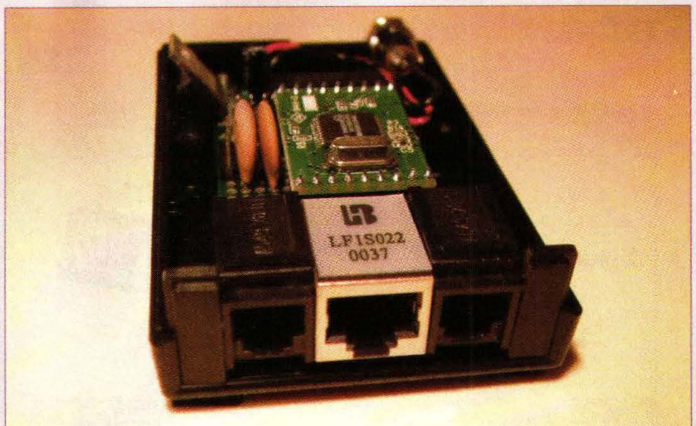


Photo 4 — Assembled into the PacTec enclosure.

Table 3

Transmission to CM11A	CM11A Response	Description
0x04, 0x66		Address A1
	0x6a	Checksum
0x00		OK for transmission to X10
	0x55	CM11A ready
0x04, 0x6e		Address A2
	0x72	Checksum
0x00		OK for transmission to X10
	0x55	CM11A ready
0x86, 0x64		Function A Dim 16/22*100%
	0xe0	Incorrect checksum
0x86, 0x64		Function re-transmission
	0xea	Checksum
0x00		OK for transmission to X10
	0x55	CM11A ready

Sending a Command

You will have to read the full SitePlayer documentation for details on configuring the SitePlayer to work on your network, and on bundling your web pages up in a binary image and downloading them to the SitePlayer itself. Having said that, setting up the web page to deliver a command string to the serial port at the click of a link is relatively straightforward. In order to do so, we take advantage of the predefined Serial Port Output object (referred to as the COM object in the SitePlayer documentation).

A simple web page with a link to turn on the device at address A1 might look like:

```
<html>
<body>
  <a href="SPtoX10.spi?com=%04%FB%04%66%06%62">
    Turn On A1
  </a><br>
</body>
</html>
```

Let's break this down a bit. The link "Turn on A1" is enclosed in an HTML anchor tag. The "href" parameter of the anchor tag is the address to go to when the link is clicked. In this case, the href refers to SPtoX10.spi, a SitePlayer Interface file. This is a special file used when sending data to the SitePlayer from a web browser (see the SitePlayer documentation for more details). The data is being sent to the COM object (indicated by the "com=") and is formatted according to the protocol defined in the previous section with a two-byte header pre-pended (see the next section). The bytes of data are in hex notation with each byte being preceded by a "%" symbol.

When the link is clicked, the data will be sent out the SitePlayer's serial port's TX line using eight bits, no parity, one stop bit, at the current baud rate (which defaults to 9600 baud). There is no handshaking. This presents a slight problem since we have already seen that the CM11A requires a handshaking protocol.

PIC Protocol Conversion

A PIC 16F84 processor was used to solve this pro-

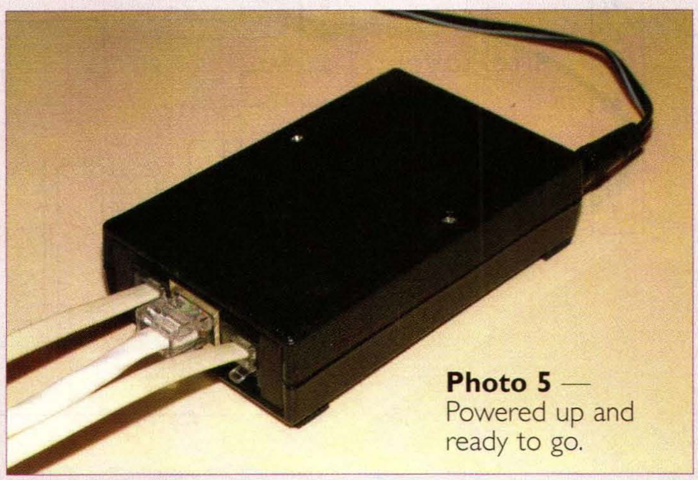


Photo 5 — Powered up and ready to go.

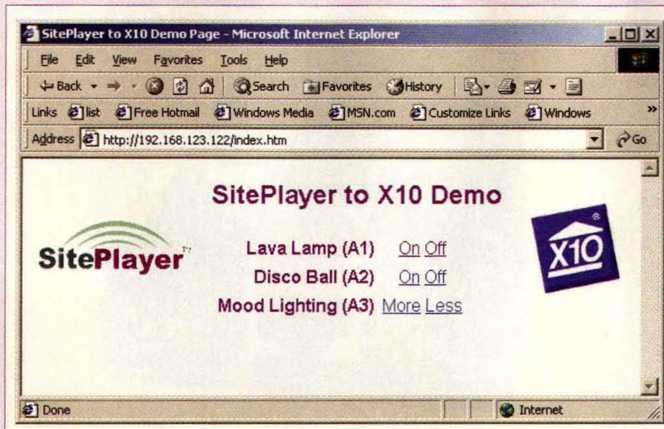


Photo 6 — Browser view of the web page defined by Listing 6.

tocol conversion issue. The PIC waits for command strings to arrive from the SitePlayer. A full command string consists of a small two-byte header followed by any number of standard two-byte and extended four-byte CM11A command sequences.

The first byte of the header contains the total number of bytes in the command string (minus the header itself) and the second byte in the header is the inverse of the first (as an integrity check). The total command string must be less than 64 bytes.

Once the full command string has been received, the PIC will transmit the individual standard and extended command sequences to the CM11A with the appropriate handshaking.

While it is waiting for a command string to arrive from the SitePlayer, the PIC will "pass through" any serial traffic between the CM11A and your PC. This allows you to use the ActiveHome software to access the CM11A to handle tasks not covered by the device described here (like downloading macros or setting the time on the CM11A).

Full PIC assembler code can be seen in Listings 1-3 which are available for download at **www.nutsvolts.com**. See Listings 4-6 (printed here and also downloadable) and Screen Shot 1 (shown in Photo 6) for a sample web page with embedded commands.

The Hardware

A schematic for the device appears in Diagram 1. The whole project was constructed on a PIC Proto-18 board (see the Parts List for details). This readily-available PCB works well for a number of reasons:

- The prototyping area was large enough for the SitePlayer module and the few additional parts required.
- The power supply was sufficient for both the PIC and the SitePlayer. Total current draw is about 100 mA.
- The area at the bottom of the board normally set up for a DB-25 connector was perfect for mounting the RJ-45 Ethernet jack and two RJ-11 jacks (although the mounting lugs at the bottom of the jacks needed to be removed for this set-up to work).

The Ethernet line connection requires both a 10BaseT transformer and an RJ-45 socket. I have used the LF1S022 Lan-Mate combined unit available from a number of sources including NetMedia (makers of the SitePlayer).

The whole project fit nicely into a PacTec HM model 2.4" x 3.8" x 0.9" enclosure. This particular

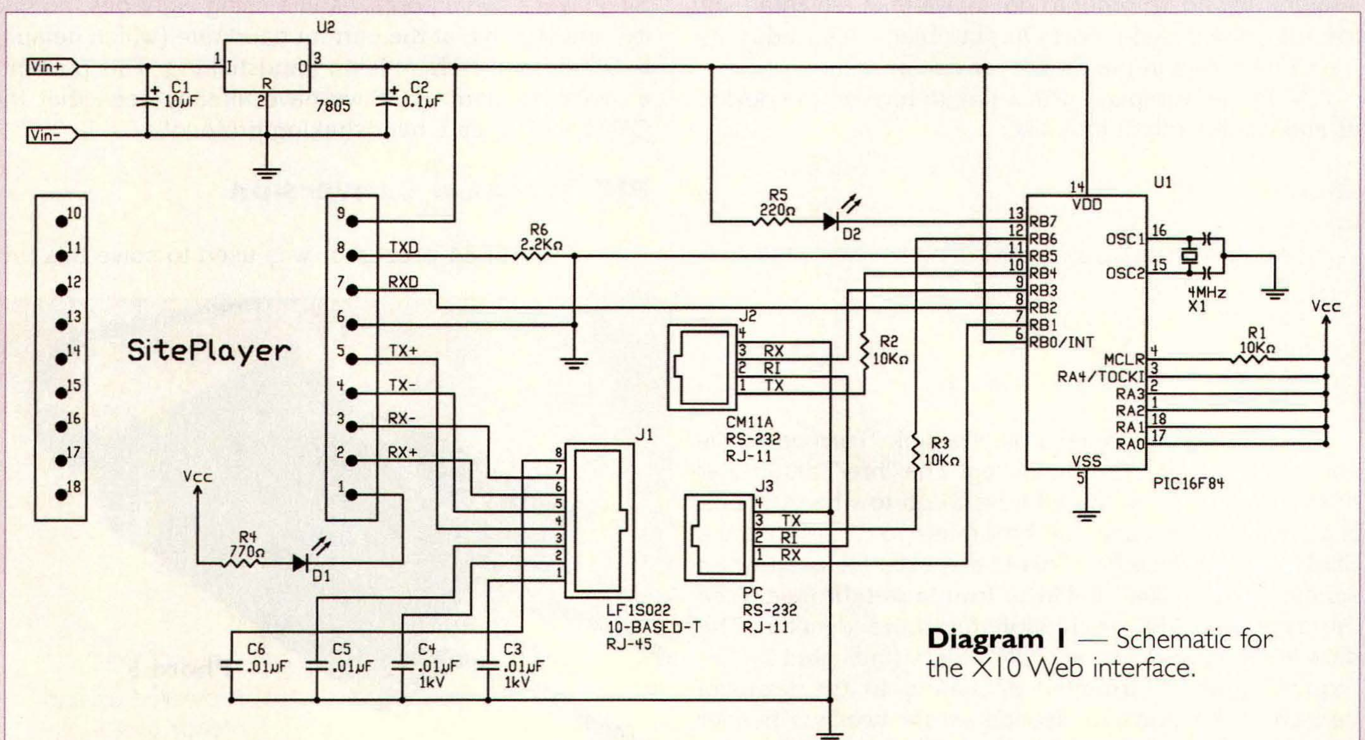


Diagram 1 — Schematic for the X10 Web interface.

model has a panel opening at one end to allow access to the various connectors (see Photo 5).

To connect the device to your network via a hub or router, you would use a standard Cat-5 cable. You can also connect it directly to a PC with a "crossover" cable.

The CM11A uses a modular headset connector (sometimes referred to as RJ-22). I used RJ-11 connectors on the device (since I could not find modular phone jacks at the time).

As a result, I had to build a four-wire "crossed over" cable to connect the device to the CM11A, and a similar RJ-11 to DB9 cable to connect to the PC. If I had it to do again, I would have used RJ-22 modular jacks on the device, which would have allowed me to use a standard four-wire modular telephone cable and the serial cable that ships with the CM11A instead.

Listing 4 — SPtoX10.spd. SitePlayer definition file.

```
;
; These are initial variables that you can place in your system
;
;$Devicename sets the name or description of the device
$Devicename "SitePlayer(tm) to X10 Demo Web Page"

;$DHCP on sets SitePlayer to find its IP address from a DHCP server
$DHCP on

;$DownloadPassword sets password for downloading web pages and firmware
$DownloadPassword ""

;$SitePassword sets password for browsing web pages
$SitePassword ""

;$InitialIP sets SitePlayer's IP address to use if no DHCP server is available
$InitialIP "192.168.123.250"

;$PostIRQ on sets SitePlayer to generate a low level IRQ on pin 11
$PostIRQ off

;$Sitefile sets the binary image filename that will be created
$Sitefile "C:\Program Files\SitePlayer\SPtoX10\SPtoX10.spb"

;$Sitepath sets the root path of the web pages for this project
$Sitepath "C:\Program Files\SitePlayer\SPtoX10"

;$Include sets the name of a file to include during make process
$Include "C:\Program Files\SitePlayer\pcadef.inc"
$Include "C:\Program Files\SitePlayer\udpsend_def.inc"
```

Listing 5 — SPtoX10.spi. SitePlayer interface file.

```
HTTP/1.0 302 Found
Location: /index.htm
```

Listing 6 — index.htm. NetMedia's SiteLinker software uses these files (Listings 4-6) to create a binary image to download to the SitePlayer.

```
<html>
<head>
<title>SitePlayer to X10 Demo Page</title>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
</head>
<body text="#8c007b">
<font face="arial">
<table width="100%"><tr><td align="left" valign="center">
  <img src="SitePlayer_logo.gif">
</td><td>
  <h2>SitePlayer to X10 Demo</h2>
  <table border="0" cellspacing="5"><tr>
    <td align="right"><b>Lava Lamp (A1)</b></td>
    <td align="center">
      <a href="SPtoX10.spi?com=%04%FB%04%66%06%62">On</a>
      <a href="SPtoX10.spi?com=%04%FB%04%66%06%63">Off</a>
    </td></tr><tr>
    <td align="right"><b>Disco Ball (A2)</b></td>
    <td align="center">
      <a href="SPtoX10.spi?com=%04%FB%04%6E%06%62">On</a>
      <a href="SPtoX10.spi?com=%04%FB%04%6E%06%63">Off</a>
    </td></tr><tr>
    <td align="right"><b>Mood Lighting (A3)</b></td>
    <td align="center">
      <a href="SPtoX10.spi?com=%04%FB%04%62%36%65">More</a>
      <a href="SPtoX10.spi?com=%04%FB%04%62%36%64">Less</a>
    </td></tr>
  </table>
</td><td align="left" valign="center">
  <img src="X10_logo.jpg">
</td></tr></table>
</font>
</body>
</html>
```

Wrap-Up and Futures

This project leaves lots of room for future "tinkering." For instance, the CM11A is a two-way interface that not only accepts commands, but returns status information from the devices it controls. The PIC firmware could be extended to monitor this information and update internal SitePlayer variables.

A transmit line from the PIC to the SitePlayer is enabled, but unused at this point, for this very purpose. These internal variables can then be used to dynamically update your web pages.

Another improvement might be to have the PIC periodically check to make sure that the SitePlayer is operating normally. There is a status command that can be sent via the serial port for this very purpose.

If there is any problem, the PIC could restart the SitePlayer via its reset line.

I'm happy to report that I was right when I started this project; it was a lot fun. I learned a great deal along the way, and hope that my work will inspire others to embark on their own journeys of discovery. **NV**

Parts List

C1	10 uF 16V electrolytic capacitor
C2	.1 uF tantalum capacitor
C3,C4	.01 uF 1kV ceramic capacitor
C5,C6	.01 uF ceramic capacitor
R1-R3	10K 5% 1/45W resistor
R4	770 ohm 5% 1/4W resistor
R5	220 ohm 5% 1/4W resistor
R6	2.2K 5% 1/4W resistor
U1	PIC16F84 Microcontroller
U2	7805 Voltage Regulator
D1	Red LED
D2	Green LED
J1	RJ-45 PCB mount jack with 10BaseT transformer (LF1S022 Lan-Mate)
J2, J3	RJ-11 PCB mount jacks (or modular headset jacks)
X1	4.00 MHz ceramic resonator with capacitors
SP1	SitePlayer SP1 Module **(www.siteplayer.com)**
PCB	PICProto18 Prototyping Board **(www.melabs.com)**
Enclosure	PacTec HM model 2.4" x 3.8" x 0.9" **(www.pactecenclosures.com)**
Misc.	0.1" Male headers, wire-wrap wire, power jack and matching 9V "wall-wart" transformer power supply, RJ-11 and CAT5 cables

A Radio-Controlled Airborne-Video System

by Phil Blake

SuperCircuits' VideoBug System makes it simple to get live video while flying your R/C airplane.

Introduction

It seems us down-to-earth folks have always had a fascination with flight. To soar with the eagles and to be free is part of what the enjoyment of flight has to offer. My fascination with flight started at an early age with the local Civil Air Patrol. Cadets wishing to learn about flight could rent the Patrol's Cessna 150 with an instructor for only $8.00 an hour. That seemed like a lot of money, back then! I continued to learn as much about flight as I could.

When "ground-based," I would head up to the local soaring slope and toss my radio-controlled (RC) glider into the thermal breeze. Now flying a Cessna 150 compared to flying an RC thermal glider shouldn't be that much different, but it is. Both are exciting, but it sure would be nice to be "up there" with the RC glider.

So way back in 1993, my fellow soaring friends and I got together to see if we could equip a glider test bed with airborne video. To help us get started with this great ambition, we turned to SuperCircuits, and their plethora of video equipment. From them, we purchased a miniature color camera, and transmitter and receiver kits. It took a few pleasurable days of work soldering together the transmitter and receiver kits, and then electrically tuning both for proper operation and range. Using a large, hand-held UHF television antenna, we pointed the antenna at the glider for best reception.

Although expensive and bulky in size, the airborne system worked to our complete delight. The received and recorded video provided hours of fascinating enjoyment. Seeing a flight video from above — where you are the pilot — is as fun and as close to being "up-there" as possible. We could finally see and feel the freedom of flight.

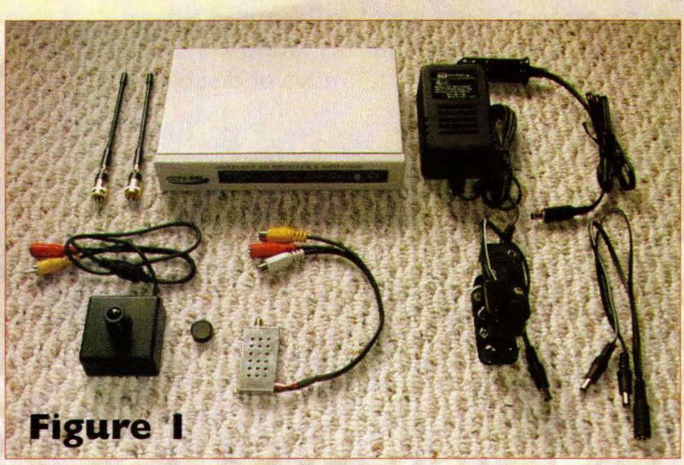


Figure 1

Back in 2000, SuperCircuits began offering a truly turnkey, miniature airborne-video system that's 100-percent plug and play. The transmitter and receiver are ready-built and tested. The color camera is mounted in a rugged plastic case. The camera readily plugs into the transmitter using the supplied RCA cables. The transmitter/receiver pair operate at 900 MHz, which is a relatively quiet, ham-radio licensed frequency band.

Improvements in technology have lead SuperCircuits to offer an even lower cost, lighter, and smaller system called the AVX-900-S2-V, 900-MHz FM Wireless High Power VideoBug System (Figure 1). This is also a complete plug-and-play video system to be used in various real-world applications. We'll be using it in a unique radio-controlled airborne-video application. Radio-controlled airborne video combines a number of skills that most of us already have. These skills include piloting RC aircraft, ham radio and, of course, basic tinkering, if you are inclined to do so.

System Specifications

Three components comprise the airborne section. They include the transmitter, the camera, and the battery pack (Figure 2). Each component is plug and play, with color-coded video and power cables. This makes set up and testing a brisk event. On the ground is the receiver, which receives the transmitted video from the airborne transmitter. For field use, a battery-powered television, together with an inverter-powered camcorder or video tape recorder, simply plugs into the video output jack of the receiver. This is almost all it takes to obtain first-rate, live video from your radio-controlled airplane, helicopter, car, or boat.

Inspecting the individual components that make up the wireless video system — first and foremost — is the transmitter. It is encased in a metal, radio-frequency shielded housing. The transmitter measures a diminutive 2" x 1" x 1/4". The transmitter is pre-wired with two RCA-type input jacks — one for video and the other for sound — and a power jack for battery power. A matching 900-MHz whip antenna screws onto the mounting ear of the transmitter. The antenna measures approximately 5-3/4" long. The combined transmitter/antenna and cabling weigh 2.1 ounces. Power requirement is 12-volts DC at 280 milliamps. RF output power is approximately 250 milliwatts, operating on the ham-band frequency of 910.1 MHz.

Figure 3

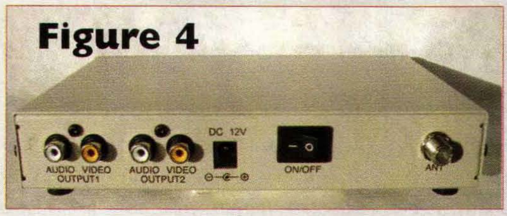


Figure 4

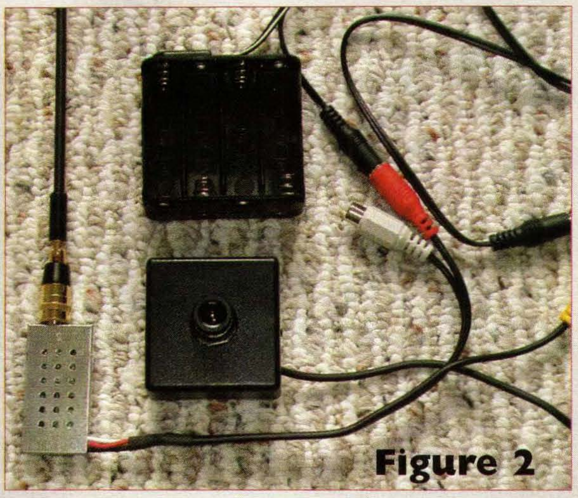


Figure 2

Next is the color camera. The camera is housed in a rugged plastic case. The video and power cable routes out from the back of the case. The case measures approximately 2" x 2" x 1". The video lens protrudes another 3/8" out from the front of the case. The camera/case and cabling weigh 2.4 ounces. The camera is a SuperCircuits PC169XS with a 4mm, medium/wide-angle, 70-degree field-of-view lens. The PC169XS delivers an impressive 460 lines of resolution, which is sharper than standard VHS or 8-mm recorders. Low-light performance goes all the way down to one lux — not night vision, but this specification is impressive for a camera this economical. The camera is fully automatic in its operation of gain, white balance, back light compensation, and stepless shutter. Power requirement is 12-volts DC at 120 milliamps. The camera's video output jack easily mates to the transmitter's matching video input plug.

The airborne transmitter and camera share an eight-cell, 12-volt DC battery pack. The battery pack includes a Y-harness to provide simultaneous power to the transmitter and camera. The battery pack and Y-harness with eight AA alkaline cells tops in at 8.5 ounces. The entire airborne system, including transmitter, camera, and batteries, will add an additional 13 ounces to your application. At 12-volts DC, the transmitter and camera together consume approximately 425 milliamps.

The last component of the AVX-900-S2-V system is the ground-based receiver (Figures 3 and 4). The receiver measures 7-1/2" x 5-1/4" x 1-1/4". On the back of the case are the color-coded, plug-and-play connections that output video and sound to your supplied television and/or video tape recorder. A matching 900-MHz whip antenna screws onto the receiver's antenna mounting jack. A supplied wall-mounted transformer attaches to the receiver's power jack. At the field, most of us will not be using the wall transformer, but rather the 12/13.5-volt DC power furnished from your automobile battery using the included cigarette lighter plug adapter. Power consumption of the receiver is 12-volts DC at 350 milliamps.

Ham Radio Licensing

The AVX-900-S2-V falls under the category of FCC licensing known to amateur radio operators as ATV, or Amateur Television. Thus, the FCC requires the operator of these components to hold as a minimum, a no-code Technician class license. I do not feel that this is a major hindrance, as the Technician class license is relatively easy to obtain; there is no code to learn and, due in part to the Internet, many testing sites are available to study for the exam and to even take randomly sampled tests on-line. Local amateur radio clubs are also of great help, and can provide you with study guides and licensing information. With a few weeks of study, I foresee that most of you will be able to pass the 35-question exam.

While making the licensing easier for most to obtain, the FCC has also raised the bar for violators. If caught using ATV without the proper licensing, the FCC can fine the operator up to $10,000.00 per day of unlicensed operation and up to six months in jail! The remedy here is to have the proper license. Again, all that is required is a Technician — no code — license.

As an added benefit, once you have obtained the license, a whole new world of communications can open up for you. Ham radio is fun and provides a helpful communication service for our local communities in the event of an emergency.

ATV Installation

Due to the lightness of the airborne components, the camera and transmitter can be mounted just about anywhere in the intended application, provided the cabling can reach between the two. It is important to place the heavy airborne battery at or near the center of gravity (CG) of the airplane. The camera and transmitter should be mounted in a foam bed to isolate them from engine vibration. Keep the video transmitter away from your airplane's radio equipment as much as possible to lessen the likelihood of radio interference, although I could find no interference, on even

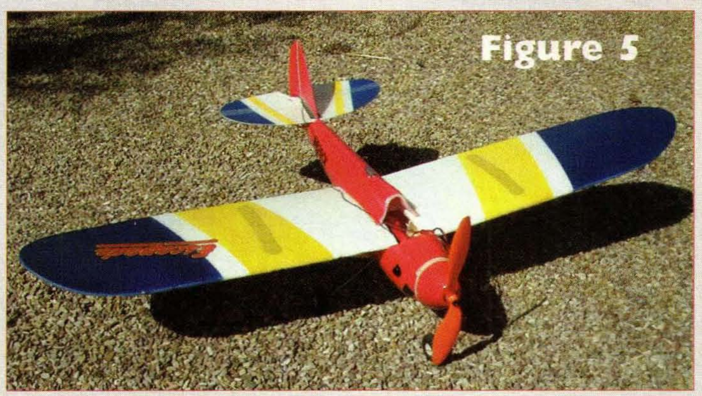


Figure 5

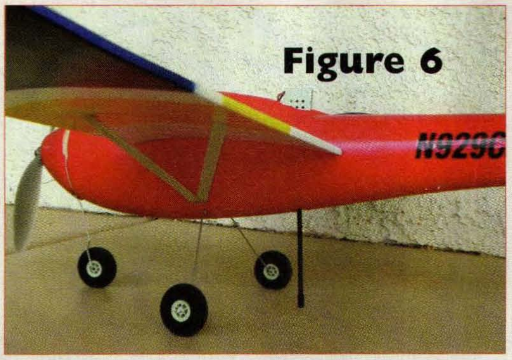


Figure 6

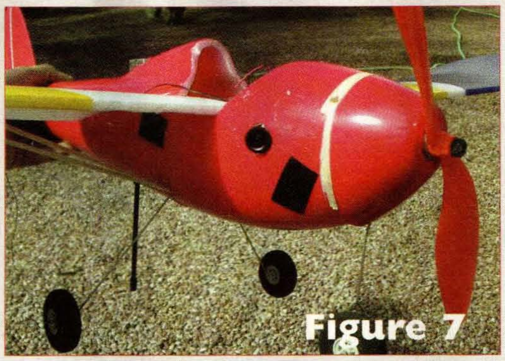


Figure 7

my single-conversion 72-MHz radio-controlled receiver.

For most of you, the installation will be quick and easy, as I previously mentioned the plug-and-play nature of the components. With this said, I preferred an alternative route! My radio-controlled activities — for the past several years — have been electric, slow-flight airplanes. Imagine no more messy fuels and oils. No more loud and powerful gas engines. This is not to say I still don't fly gas, it's just that I would rather not. For me, after a long day of work, little is more pleasurable, simple, and convenient than tossing my 11-ounce slow/park flyer from the front yard for a 30-minute ride to relaxation. What if I could reduce the 13-ounce weight of the airborne-video system to make it light enough to accompany a ride on one of my slow/park flyers? The size of the airborne system will fit, but something will have to be done to minimize the weight.

Cut and Chop Time

I would like to mention that SuperCircuits has recently introduced an ultra-lightweight camera/transmitter pair, more suited for slow flyer applications. I intend to report on this new system in a future article. But for now, my technique will focus on tinkering to see how much I can reduce the weight of this airborne-video system. I would like to stress that this is not the preferred technique, as the AVX-900-S2-V is a wonderful plug-and-play system for most gas-powered airplanes, electric-powered cars, or even two-meter gliders!

My Great Planes Escapade park flyer has seen several dozens of flights around my neighborhood (Figure 5). Each has been hand-launched from my front yard. On a good day, I can average a 30-minute flight with the help of some late afternoon warm, rising air.

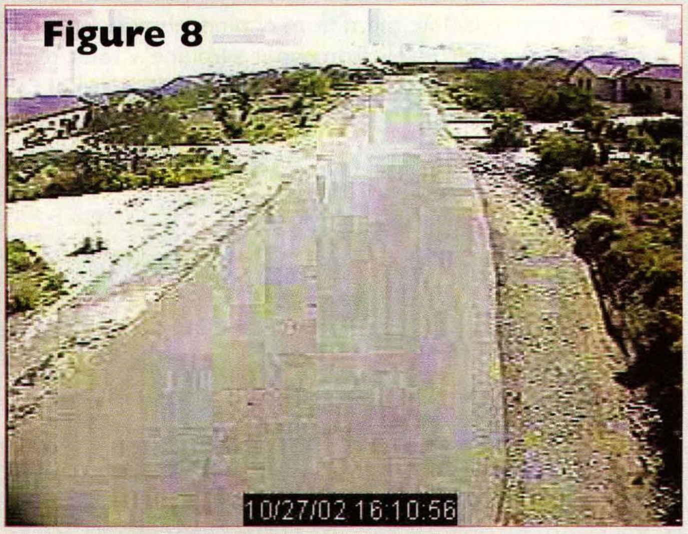


Figure 8

The AVX-900-S2-V will provide an excellent opportunity to take an airborne peek around the neighborhood. My foam-constructed Escapade, with its 40-inch wingspan, has an advertised weight of 13 ounces. I use NiMH batteries as the power source for the airplane, therefore my Escapade only weighs 10.8 ounces with the flight battery.

Here is how I lowered the weight of the airborne-video equipment. First, I removed the camera from its plastic case. From the camera and transmitter, I cut off and removed their RCA and power plugs. I then hard-wired the two together, splicing in a miniature plastic power plug to the camera and transmitter power lines for their separate battery power source. I had a surplus seven-cell, 110-mAHr NiCD, which will be used to power the camera and transmitter for this application. Note that it is not advisable to power the transmitter/camera from the airplane's radio control/motor drive source, as glitches in the servos can and will occur.

Through experimentation, I found that the transmitter could operate as low as 6.5 volts before dropping its signal. The camera is good all the way down to five volts. In testing, the surplus 110-mAHr, 8.4-volt pack provided about 15 minutes of video "down-link" power, which will be adequate for this application. The all-up weight for my "cut and chop" airborne-video system went from 13 ounces all the way down to 4.2 ounces, including the NiCd pack.

To maintain the center of gravity, I fooled around a bit and found a good CG with the transmitter installed mid-fuselage (Figure 6). I poked a hole through the foam fuselage up front for the tiny camera (Figure 7). The additional video battery pack rested securely in the lower section of the front fuselage. Once installed, the Escapade's flight weight went up to 15 ounces, or two ounces heavier than advertised. In spite of the additional weight, I feel the Escapade will be able to sustain flight.

Flight Video

I set up the ground-based video receiver with stock antenna to have full coverage of my flight radius. The video out of the receiver went to a VCR. The VCR's video out connected to a portable TV. Whoops! Before taking off, don't forget to press the Record button on the VCR!

Out in the front yard, I turned on the airborne video and the airplane's radio. I performed a range check and could detect no interference. My assistants relayed they were receiving the live video — ready to launch! I applied motor power and hand-tossed the Escapade upward. The additional weight did not adversely affect flight perform-

Figure 10

Figure 9

ance, nor were any radio glitches detected.

I wondered what the airborne video was sending. I flew around the neighborhood, gaining altitude along the way. Total flight time was right at 15 minutes, and it was time to touch down on the street; I could hardly wait to see the video! I was not disappointed, either.

The tiny PC169XS color camera produced some of the best visuals I have ever seen. The views were terrific, with only an occasional amount of video noise. In reviewing the video, I even saw several birds flying nearby, which I also spotted during the flight! The landing on the street looked pretty good, too!

Please note that the captured images, (Figures 8, 9, and 10) do not serve justice to the actual video. The video capture card on my computer could only capture the images in 320 x 200 format; thus, the pictures shown are distorted and considerably grainy in appearance. For the best visuals, place the camera with the lens pointed below the horizon. This will allow the camera's automatic gain setting to be relatively low, thereby allowing better exposure of the ground below.

If the camera is aimed so that most of the sky is visible, then the ground will appear quite dark, again due to the automatic gain setting of the camera. Another item worth noting is that the smoother the airplane is flown, the better the video looks. Calm air or an airplane flying near the limits of its power curve, produces the smoothest, most realistic video. Needless to say, it's a really "neat" experience to see a flight of the neighborhood taken from an eagle's perspective.

Conclusion

The AVX-900-S2-V opens up a whole new world for the modeler/experimenter enthusiast. Best of all, this system is remarkably user-friendly, thanks to its plug-and-play colored connections.

There are many avenues to pursue using live video. Imagine using a wrap-around, head-mounted goggle to display real-time video! What a visual treat this would be!

I hope that you have enjoyed this article on airborne video. I look forward to presenting you with additional products and articles that are both high tech, yet simple to use, and reasonably priced. NV

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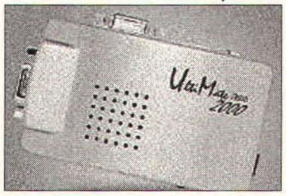

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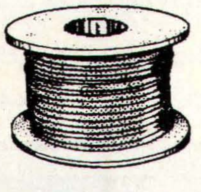

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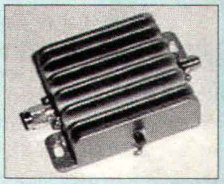

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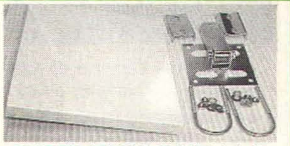

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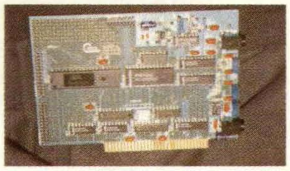

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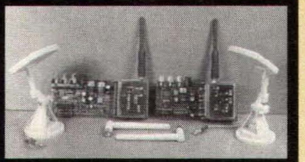

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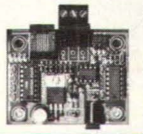

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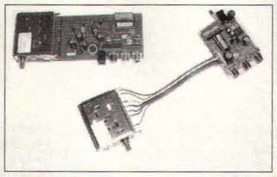

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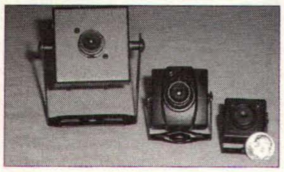

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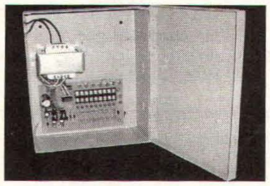
CAMERA DISTRIBUTION Box, XF-250-DC/XF-250-AC.



Connect your cameras directly to power source with screw terminals or plug in using a 2.1 mm connector.
Special price: $59 (DC version) and $49 (AC version)
Can use pre-molded 50 foot video/power cable A-402-CA $15.
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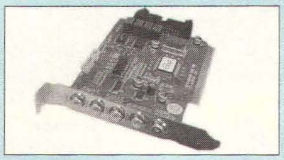

4 PORT video capture card with remote internet access, **DVRC-4; $339**. Remotely view any 4 NTSC video cameras over your internet connection. Sophisticated motion sensing option allows camera to be activated by motion or time. 500 MHz or higher; 98/2000/XP, NT compatible. Installation time under 10 minutes. 16 channel unit is also available, bundled with PC.
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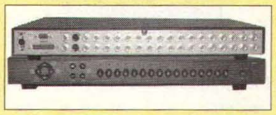
16 CHANNEL MULTIPLEXER MUX-1600



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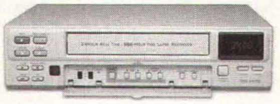
40 DAYS and 40 NIGHTS RECORDER



Time lapse, with remote, can be activated by either contact closure or continuous duty operation with standard T-120 tape. ES-8960 at **$339.**
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CLASSIFIEDS

ROBOTICS

"Where It Is and How to Get It"

Robotics Resources

Roundup of Serial Servo Controllers

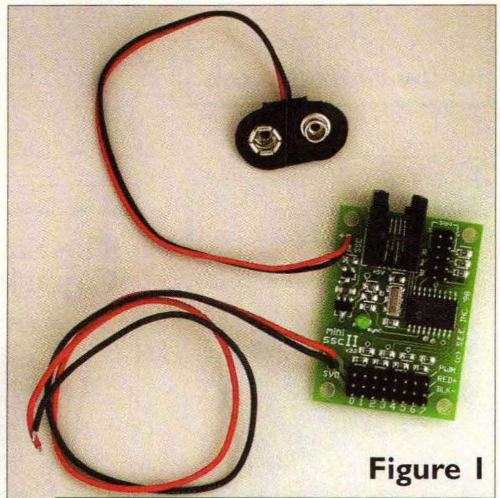

Figure 1
The Mini-SSC II servo controller from Scott Edwards Electronics.

Radio control (R/C) servos have become a mainstay in amateur robotics. In one small and relatively-affordable package, you get a gear motor, H-bridge, and control electronics. They're easy to interface to most any microcontroller, requiring no additional circuitry. R/C servos can even be controlled using a simple 555-based circuit.

For robotics, servos can be employed as they come from the factory, for example, with walking robots. In this application, the servos provide precise positional control over an arc of 90 to 180 degrees. With this set-up, it's possible to engineer specific "walking gaits" for legged robots, and experiment with different movements. Most R/C servos can also be modified to allow for continuous rotation. They lose the ability to be precisely positioned when modified, but they're great as the drive motors for wheeled and tracked robots.

In either application, the servo must be commanded using a series of pulses; they can't simply be turned on and off, like an ordinary DC motor. The pulses repeat about 50 times each second (50 Hz or every 20 milliseconds). The duration of the pulses — nominally from 1.0 to 2.0 milliseconds — determines the position of the servo wheel. A signal of 1.5 milliseconds positions the servo in its center. For a servo modified for continuous rotation, 1.5 milliseconds stops the servo; shorter or longer pulses cause the servo to rotate in one direction or the other.

Because of variations in servo design, the precise timing of the pulses must be determined empirically. For example, on some servos modified for continuous rotation, a pulse of 1.64 milliseconds might stop it. It's up to the robot builder to determine the proper timing requirements. Fortunately, this isn't as hard as it sounds when you're using a microcontroller. Timings can be quickly changed in software.

Most robots — wheeled, tracked, or legged — have at least two servos, and some have as many as 18 or 20! Controlling multiple servos can be taxing on a microcontroller because of the timing requirements. Recall that the pulses must be repeatedly sent to the servo. If you're using just one microcontroller, it must continually "refresh" its servos, as well as perform any other tasks you want your robot to do.

Some microcontrollers are better than others at running multiple servos. Both the IsoPod (New Micros, **www.newmicros.com**), and the OOPic II (Savage Innovations, **www.oopic.com**) are designed to run multiple servos and still leave room for other tasks.

Fortunately, even if you're not using one of these micros, you can still command multiple servos by using a serial servo controller. These controllers accept simple serial data input, and then — completely separate from your microcontroller — operate all your servos.

While servo controllers sound like a panacea, they aren't without their shortcomings. The most serious is that there is a limit to the number of servos they can operate. Most all servo boards command each servo one at a time. Assuming a 50 Hz refresh rate, the servos need a new signal every 20 milliseconds. Worst case, each servo needs the maximum 2.0 millisecond pulse, and there must be some time left over to process the incoming serial signal. As a result of this data bottleneck that must be repeated each second, most serial controller boards are limited to eight servos. If you need to control more servos, most designs allow you to daisy-chain additional boards.

How They Work

Servo controllers operate multiple radio control servos from a single RS-232 or TTL-level serial line. The benefit of servo controllers in robotics is obvious: rather than devote the majority (or all) of a robot's controller to servo functions, this task is handed off to a "co-processor" that does all the work.

In operation, the robot's computer or microcontroller sends a short set of instructions to the serial controller, telling it which servos to operate, and where to move them to. In the most basic serial data scheme, these instructions are sent through a simple one- or two-wire serial connection. In the typical two-wire connection, one line is used for the actual data, and the other line is used as a synchronizing clock. Even those microcontrollers that lack true serial communications capability can use the two-wire approach by applying what's know as "bit banging" — sending data to a pin one bit at a time.

There are a number of serial servo controllers on the market. Here are over a half dozen that you may want to investigate further.

Mini-SSC II (Scott Edwards Electronics)

www.seetron.com/

The Mini-SSC II set the stage for the other servo controllers that followed and, as a result, many products are functional duplicates of this one. The Mini-SSC II ($44.00) connects to a serial communications port at 9,600 bps or 2,400 bps, and controls up to eight standard hobby servos at one time. It's possible to link several Mini-SSC II boards in parallel, and therefore, control even more servos.

The data format used by the Mini-SSC II has also become something of a standard. Each command from your microcontroller is composed of three bytes: a "preamble," a servo board/servo address, and servo position. The preamble is hex FF (decimal 255); when the servo board receives this byte, it knows to look for the second two bytes. The board/servo address tells the controller which board (if using more than one) and which servo is to be commanded.

Finally, the position byte tells the servo where you want it to go, in 256 discrete steps. Assuming an unmodified servo with a full rotation of 180 degrees, the rotational resolution is 0.7 degrees. For example, if 128 centers the servo, 129 positions it to the right by 0.7 degrees, and so forth.

SV203 (Pontech)

www.pontech.com/

The Pontech SV203 series of serial servo controllers operate up to eight standard servos, at serial speeds of 2,400, 4,800, 9,600, or 19,200 bps. Like the Mini-SSC II, each board can be assigned a different address, and therefore, you can control multiple banks of eight servos.

The basic SV203 retails for $59.00. The upgraded SV203B/C boards ($79.00 and $85.00, respectively) also feature infrared, digital I/O, and on-board program memory, allowing them to be used in standalone mode, without a controller or computer.

Servo 8T (BasicX/ NetMedia)

www.basicx.com/

The Servo 8T ($39.00) controls up to eight servos, and eight units can be daisy-chained to control up to 256 servos. The Servo 8T supports serial speeds up to 19,200 bps. What sets this controller apart from the others is that it incorporates force feedback for each servo. This information is communicated back to the computer or microcontroller, and can be used to moderate the position of the servo.

The Servo 8T requires a different command string than the Mini-SSC II, though it's just as easy to use. The preamble character is >, followed by two bytes — one for the board, one for the servo. The last two bytes indicate the command you're sending (e.g., goto position, get position, goto home, etc.), and the position of the servo. The 8T has a handy "turn off" feature whereby no control signal is sent to the servo. This has the effect of de-powering the servo. (To be clear, the servo still receives operating voltage, but because it's not get-

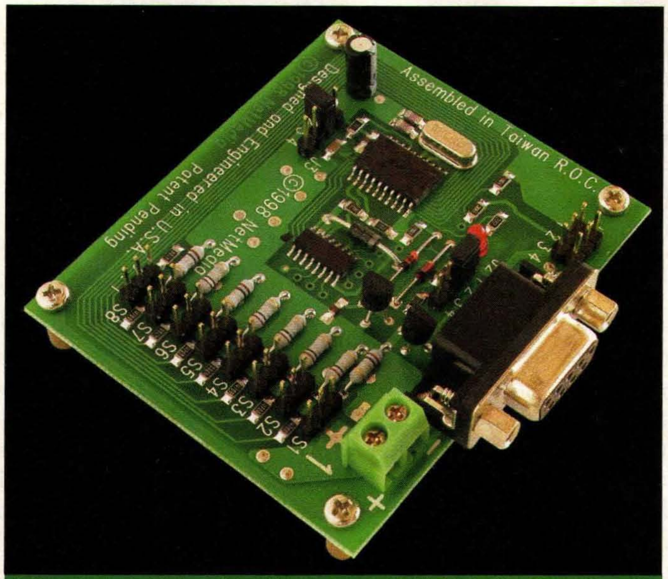

Figure 2. The 8T servo controller from BasicX (NetMedia).

ting any control signals, it doesn't attempt to move anywhere.)

FT639 (FerretTronics)

www.ferrettronics.com/

The FT639 is the smallest servo controller of the lot discussed here; everything is contained in an eight-pin integrated circuit. The chip can control up to five servos, and supports 2,400 bps communications. The FT639 cannot be paralleled to control additional servos; however, the company offers another product — the FT649 — that can control five FT639 servo controllers (for a total of 25 servos, which is usually more than enough for anybody).

The FT639 by itself is $14.99. You need to mount it on a circuit board and provide headers for signal lines and power. Or, you can purchase the chip with a custom circuit board for $20.99. The circuit board is also available separately for $6.99, and the board comes with a five-volt regulator.

ASC16 (Medonis Engineering)

www.medonis.com/

The ASC16 operates up to 16 R/C servos. To help separate it from the rest of the pack, the product also sports eight high-current digital outputs (up to 250 mA each), and eight inputs configurable as either analog or digital inputs.

The ability to control more than just servos can be a great feature. For example, you could operate a small solenoid, or light a bank of LEDs. If your robot's main microcontroller lacks analog inputs (like the BASIC Stamp 2), you can use the ASC16 as a kind of data acquisition co-processor. The ASC16 is one of the more expensive serial servo controllers ($119.00), but if you need the extra I/O, you could actually save money by combining it all in one board.

Pololu Servo Controller (Pololu)

www.pololu.com/

Provided in kit form (you must solder it together), this controller operates up to 16 servos, at data rates from 1,200 and 19,200 bps. Price is $47.00.

Ohmark Digital Servo Controller (Ohmark)

www.ohmark.co.nz/

The Ohmark DSC (about $30.55 in US dollars) controls up to eight servos, and can be daisy-chained to operate up to 32 servos. In addition to being able to set the position of the servo, the DSC can control the "rate" or speed of the servo movement — this is a unique and great feature! And like the BasicX Servo 8T, the DSC can disable individual servos so that they do not consume power.

Note that Ohmark is based in New Zealand, but they will ship most anywhere. As of this writing, they lack a distributor for the US.

And One in Development

As I was finishing this column, a friend told me privately of a new serial servo controller he's developing that can operate up to 32 servos on a single board. The controller board uses a fast PICmicro and a unique programming scheme whereby it commands the servos in parallel, rather than one at a time. This allows it to control 32 servos (expandable by adding more boards), without sacrificing the 50 Hz refresh rate.

If you're interested in this product, drop me a line at the email address listed in this column, and I'll pass on your name to the developer when he's ready to announce his new product.

Roll Your Own Serial Servo Controller

In addition to commercial serial servo control products, a number of websites demonstrate how to make your own, typically with a PICmicro controller and assembly language or Basic programming. Here are two:

16-Channel Serial Servo Controller
www.seattlerobotics.org/encoder/200106/16csscnt.htm

5-Channel Serial Servo Controller
www.frii.com/~dlc/robotics/projects/botproj.htm NV

Make Contact. Got a great source for a nifty robot, kit, or component? Feel free to pass it along to me at: **robots@robotoid.com**.

The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Why Good Ideas Aren't Good Enough

There is the urban legend about this smart young engineer who came up with a good idea and sold it to a big company for enough money to retire. Like any good legend, there is some small truth to this ... very small. The truth is that this can happen if you or your parents happen to know a prominent businessman or politician. Unfortunately, if you are reading this, then you probably don't have those types of connections to easy millions.

The sad truth is that good ideas are not rare. Every reader is certain to have had an idea that is potentially profitable. Everyone — at one time or another — has said: "Gee! I could make a lot of money selling these." Therein lies the problem. Everyone has good ideas. You have to compete with everyone else!

How can you sell your idea to your boss, when your boss is trying to sell his idea to *his* boss? How can you get an outside company interested in your idea when hordes of its own employees are clamoring for research funds to develop *their* own ideas? The short answer is that you aren't likely to. But, hope is eternal.

This month's column will show you how to approach companies properly, why companies are reluctant to accept outside ideas, the costs required to develop an idea, and the most likely way to make money from your idea. Also, this is just an overview to point you in the right direction. Books could be written on this subject (and probably are).

It's a Risky Business

First of all, it takes lots of time and money to develop an idea into a product and market it successfully. As an example, let's use a simple test instrument that consists of a single PCB with a few switches and a microcomputer. How much do you think it will take to develop it into a product from just an idea? Let's work out a rough estimate.

We'll need a design engineer for the hardware, a software engineer for the programming, someone to lay out the PCB, as well as overhead in the form of engineering and support staff. Let's assume it takes three weeks to design and test the hardware and four weeks to write and debug the software, with one week for PCB layout and miscellaneous odds and ends. This is about eight weeks or about 320 hours (and this is a very fast turn-around).

The loaded labor cost (includes salary, benefits, overhead, and everything else) is about $75.00 per hour for a development cost of $24,000.00. Remember, this is for a small, simple idea with an efficient development cycle. It can often cost two to four times this much. This is especially true for new products that require learning new techniques or procedures.

Next, as we go into production, we'll need to train people to test, assemble, inspect, troubleshoot, and package the product. In addition, we'll have to market the product. This means advertising, training salespeople, getting feedback from customers, and so forth. All of this requires time and money. It is not at all unusual for a company to spend about $100,000.00 of up-front money and up to six months of time to converting a simple idea into a product.

Now we add a very practical consideration. How many instruments must be sold to recover the development and marketing costs? How long will that take? Typically, if a company can't recover those costs within a year, they probably won't pursue the idea. Now, if you were running a company, would you spend $100,000.00 on some stranger's idea? And, remember too, many new products fail. Now, you can start to see why trying to sell an idea is difficult, but we will later see ways to improve the odds.

Note, small companies are generally more efficient, but limited in their resources. They are more receptive to small product ideas. Large companies, with a lot of bureaucracy are less efficient, but have larger resources. They are more receptive to bigger product ideas.

Be Brutal, Stubborn, and Patient

First of all, is your idea good? In order to determine this, talk to others who are in the field. You shouldn't have any problem because your idea should be in your field and those "others" should be your co-workers, friends, boss, teachers, etc. (If your idea is not in your field, don't waste your time.) Be objective and ask your reviewers to be, too. Be brutally honest in your evaluation (a hard thing to do). Identify and examine all the weak points. What makes your idea good? It must clearly, repeat *clearly*, show a significant, repeat *significant*, technical or financial advantage over all existing ideas. If it can't show this, either abandon it or improve it. It won't succeed as it is.

It is important to realize that probably very few people will love your idea. Everyone will have something to say, suggest some way to improve it, find something wrong with it, etc. Use this information to make your idea better. Don't fall in love with it! No idea is perfect. Criticism of your idea is not criticism of you. If you invest feelings in your idea, you almost certainly will make bad decisions.

However, sometimes you have to be stubborn. There are many cases where experts have panned an idea only to have the future prove them wrong. But, if the reviewers don't like your idea, it makes it much more difficult to sell the idea as an idea. You'll have to invest a lot of time, effort, and money before you are likely to get anyone else to seriously consider it. (More on this later.)

Remember, good ideas are not rare. Successful good ideas are rare. This means that you shouldn't be afraid to defer a good idea. Often, time causes circumstances to change and that can make your idea more attractive and more likely to succeed. The best chance for an idea to blossom is to present it when the need arises.

So keep a list. Whenever you get a good idea, write it down. Every year or so, re-examine the list. Remove ideas that are no longer viable. (I've got a list that I limit to 50.) Be patient.

Formal or Informal Approach

There are two basic ways to present your idea: formally and informally. The informal way is just talking about it. (Hopefully to someone who is interested.) You can *never* expect anything to come of this. Simply, people forget, get confused, get busy, or just don't know what to do with it. The most you can expect from an informal approach is the expression of interest. If you find someone who is interested, then ask to formally present the idea. Please note, if the person is not interested, don't waste his/her time and good will by pushing. It will only annoy them and make it much less likely that they will give you any future consideration.

The formal approach typically starts with a "White Paper Proposal." This is a document that provides an overview of what the idea is and does. It does not say how the idea operates. Nor does it include any sensitive or proprietary information. This is a teaser. It sells your idea technically and financially in general terms. It compares your idea with others and identifies why your idea is better. Typically, it's a couple of pages long. Its sole purpose is for you to be granted an in-person presentation.

This is a meeting with business and technical decision makers where you present your idea in all its detail and answer all questions. Here is where your idea flies or dies. If you think this sounds like a resume/interview, you're right. The only difference is that you are selling your idea instead of yourself. (Note, on some occasions, your proposal may be the only contact you will have. In this case, the proposal must be detailed, complete, and probably fairly lengthy.)

Get an Inside Contact

Suppose you have an idea for a new test instrument. You write a formal proposal to Agilent (ex-Hewlett Packard) trying to sell the idea. First of all, who do you send the letter to? If you address it to the company, it will probably end up in the Public Relations Department. Then you'll probably get a polite thank you note and that's it. Don't think that they'll route it to the right person. They're not engineers and it's not their job. Their job is to send out polite thank you notes, not bother high-level engineers who have better things to do. You must have the proper company contact before even considering sending a proposal!

How to Make Contacts

There are a number of ways to find a contact. The best is to attend a seminar or trade show. Here, you meet field engineers and application engineers. Talk to them and find out if your idea interests them. If so, they will give you a name to contact. When you contact that person be sure to say who and where you got their name from. This is important because it gives you credibility in the form of a reference.

You can also talk to a salesperson from the company of interest. They may be able to provide a name. However, they are somewhat removed from the engineering department. Likewise, you can view the company's website and try to figure out the best person to contact. This approach is somewhat hit or miss.

If you have your own company, there are other options. If your target is a small local company, you can sometimes aim high. With small companies, "the principals" (owner, president, etc.) are often quite accessible by telephone (but you must know their name). They may be willing to talk. Especially to someone who knows about the company and is friendly, professional, and confident. Always do your homework!

Know about the target company's products and philosophies. Know your idea completely. There is nothing worse than being unable to answer a simple question about it. (One method of getting a small company's principal's name is to call that company and ask the receptionist who the "principal design engineer" is because you want to know how to address a letter. Then wait two weeks and call back asking for that person. Be prepared to answer "What is this in regards to?")

How to Improve Your Likelihood of Success

The most important aspect of selling anything is communication. If you can't express yourself in a way that clearly describes your idea, no one will be interested. No one will work at trying to understand you. They'll just look at each other, shake their heads, and say "this doesn't make sense."

Your proposal must be aimed at the specific company you are targeting. You must show how the company can make money with your idea. Always remember, companies are in business to make money! That is their only purpose. Your proposal must quickly and clearly show them this. You must demonstrate to them why their particular company is most suited for developing and marketing your idea. Be technical enough to be clear, but don't use technical jargon if you can avoid it. Don't use a writing style that is forced because it often sounds pompous or condescending or just plain odd. Be simple and clear and professional. Write so you can't be misunderstood.

Your personal presentation is just like an interview. Wear a suit. Be confident and friendly and professional. Be prepared for any questions ranging from conceptual, technical, financial, and maybe even legal issues. Be able to address development, production, and testing concerns. Have a feel for marketing. You certainly may not be able to answer every question on every topic. However, you must appear competent. (Don't ever fake an answer ... say "I don't know, but I'll find out.") Yes, this takes work. But, as Edison said, success is 90% perspiration and 10% inspiration. Just remember to reverse the roles. Would you spend money on someone who waved their arms and make vague statements?

More Work Means Better Odds

You can make a huge improvement in your chances for success by making a model or prototype of your idea. A model is a non-functional object or device that illustrates the important aspects of your idea. Sometimes, a computer model is sufficient. It's much easier to sell an idea if someone can see how it works. It also provides you with some credibility. It shows that you've worked at your idea and put effort behind it. Obviously, the better the model, the better the odds that there will be interest.

If a model is good, then a working prototype is even better! This proves that the concept is sound and removes a significant amount of risk in the development cycle. It provides answers to technical problems and clearly shows how the idea functions. It reduces time and money needed to develop the idea.

However, the best prototype is a "Production Prototype." This is not just a working model. It is a true product sample. It is functionally identical to the expected product. The only difference between this and a true product is that the "tooling" (case, cover markings, and other custom non-recurring costs) is simplified. (Note, a real printed circuit board is required. No perf board or point-to-point wiring should be used.) A production prototype should also include an operator's manual, testing procedures, parts list, assembly procedures, software listings, and so forth. Of course, this is a lot of work. But, this work provides you with credibility and it eliminates risk from the company. Remember, a company exists to make money. By providing them with a product, rather than an idea, they are much more likely to accept it. All that they will have to do is market it. There is essentially no risk or cost for the development process. You've already done that. And, if your idea clearly provides a technical or financial incentive, they will see how to market it. It becomes an easy decision for them.

Your Own Company?

If a company accepts an idea, they may pay a 1% to 2% royalty. If they accept a product, the royalty will probably be around 5% to 10%. (Also, expect some on-going paid contract work until they get into production.) This doesn't sound like a lot of money. And, it probably isn't. But, you've put in relatively little money and effort. You spent a couple of months or so building a production prototype and then you get years of royalty checks mailed to you. That's not bad.

Of course, you could sell your product yourself and make much more money. Naturally, this takes much more effort. But the likelihood of making money with your idea is much more certain and completely under your control. If your idea is good and you are dedicated to it and willing to really work long and hard, this may be the way to go. It will take a fair amount of front-end money, but this may not have to be excessive, if you do a lot of the work yourself. You market, you sell, you advertise, etc. Many small companies fail because of bad management rather than a bad product.

Look around your town or city. Look at all the small companies that grew into larger companies. These are all ideas that were good and successful. This is the most likely way to make money with your idea. You develop it. You sell it. You make all the profits from it. And, after it's successful, you sell the company and retire! Just like Bill Gates!

Odds and Ends

Naturally, before you make any technical presentation or provide any company or individual with sensitive or proprietary information, you should have them sign a non-disclosure statement. This is just an agreement that they acknowledge that your idea is yours and that they will keep all information confidential. There are many types of non-disclosure statements. A patent attorney will probably provide a basic one for you free, if you ask nicely. In any event, it should be fairly inexpensive. A company may want you to sign their non-disclosure statement. This is normally not a problem. But, always read and understand any legal document you sign. Note, no reputable person or company will balk at signing a standard non-disclosure form.Don't get involved with any marketing or patent companies that promise to develop, patent, show, and sell your idea for just a few dollars of up-front costs. Buying lottery tickets is a better investment. True marketing is expensive because it is labor intensive.

If you own your own business, it is possible to get government funding to develop your idea. (But it's not likely. There's a lot of competition for free money.) There are a number of government agencies that fund research and development. The most likely agency is the Small Business Agency (SBA) that provides SBIR grants (Small Business Innovative Research) at **www.eng.nsf.gov/sbir/**. The paperwork is significant and the lead time is measured in years. If you are not a company, a local small company might be willing to partner with you. This is especially true if you do the paperwork and they get most of the money. (You would be a paid contractor.)

Conclusion

Good ideas take a lot of work to be successful. This is because there are so many good ideas and because they need money and time to develop into real products. Companies are reluctant to risk time and money on an unknown individual. But, by developing your idea — on your own — you can greatly increase the likelihood of making money from it. **NV**

Exploring and Experimenting With Lasers and Their Properties

Laser Insight

Interferometers, interference fringes, and their interpretation

This month, we are going to cover some more new ground. Interferometers were invented even before the laser was a remote possibility and, in themselves, are very interesting. I'm sure that most readers who have an interest in this kind of thing have heard about the famous experiments performed by Michelson and Morley in 1887, in which they tried to prove (or perhaps, disprove) the existence of a luminiferous 'ether' on which light waves were carried.

The experiments became known as the world's most important scientific failure, because it failed to prove anything. The type of interferometer that was used for these experiments became known as the Michelson interferometer, and has evolved into a number of forms since its invention. The experiments performed by Michelson and Morley relied on the interference of light waves to detect a change in the speed of light, but more on this later.

If a beam of light is considered as a wave motion — similar to water waves or sound waves — then it is acceptable that when two waves emerging from different sources pass through or intersect each other, there will be some interference of the respective wavefronts. Some of these wavefronts will oppose others, making them reduce in amplitude, while others will reinforce, making these other wavefronts higher in amplitude. This cancelling and reinforcement of the colliding waves depends on the relative amplitudes and phases at the interfering points.

Similarly, there are now devices on the market that cancel or at least reduce sound waves by producing another sound, equal in amplitude, but opposite in phase to the offending noise. Most construction workers are supplied with these devices, if they are to work around high-noise level equipment.

This interference effect is certainly seen to be so in water and sound waves, and is easily demonstrated, so does it work the same with light? Well, the short answer is yes, it does behave the same (for our purposes, anyway). We'll not go into too much detail about the how's and why's this time. There have been many books written on this subject, and I don't have enough space in this column to do justice to such a profound subject. It deserves much more space than I can allow here, so for now, we'll take it for granted.

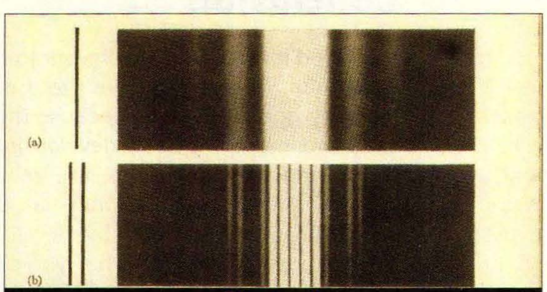

Photo 1

When two beams of light from different sources interfere, the wavefronts add. Due to the differences in arrival time of the wavefronts, there may be constructive interference, destructive interference, or some combination of the two. The wavefronts add positively or negatively, as it were, depending on their relative strengths and phases. The results of all this interference are a series of light and dark areas.

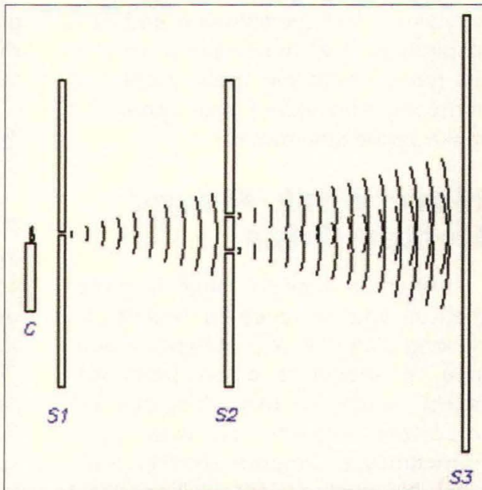

Figure 21-1: Young's experiment.

Do you remember Thomas Young's slit experiment? The English scientist Thomas Young had thoughts about the wave nature of light many years ago, and performed an experiment in 1800 to demonstrate this wave nature, through the interference effects of light rays. The experiment was witnessed by many important people in the scientific community, and went a long way to reinforce the belief that light was a wave motion, rather than the corpuscular motion proposed by Sir Isaac Newton, 150 years earlier.

Figure 21-1 shows the experiment. The screen S1 has a narrow slit in the center. Screen S2 has two narrow slits. A light source C is placed behind S1, and the light emitted from the slit is allowed to fall across the two slits in S2. Light transmitted through the series of slits is allowed to fall onto a flat screen S3. Young found that if either of the two slits in S2 were covered, the image falling on the flat screen was a broad band of light with some slight edge diffraction, as you would expect. However, when both slits were open, S3 showed an image composed of a series of light and dark bars. A view of what Young saw is shown in Photo 1.

The corpuscular theory cannot explain why a point on the screen would be light when one slit is open, but dark when both slits are open. But the wave theory could. The experiment lent great strength to the wave theory, and it became widely accepted as the most likely explanation of the nature of light.

Before this, the scientific world was torn between this and the corpuscular theory of light. Many believed that light consisted of particles because of shadows. If light were composed of waves, why then, can we not see around corners? Sound is a wave motion, and we can hear around corners, so why not with light?

It is now commonly accepted that light actually has a dual nature; it exhibits qualities of both waves and particles. But I digress, I want to show you some examples of interference that you can see for yourself. Perhaps we can discuss the nature of light some other time.

Want to see some interference fringes? The simplest interferometer can be made by placing two plane mirrors face-to-face as shown in Figure 21-2. If you use a silvered mirror, make sure it is the lower one. (If you use a silvered mirror on top, you won't be able to see through it!) This interferometer is of the Fizeau-type and tells you — among other things — how closely those mirror surfaces are matched. Figure 21-3 shows a simple set-up using a single color light source, and two flat mirrors placed one on top of the other, with their reflecting surfaces in contact. It is assumed here that there is either no coating, or at least a transparent coating on the mirror surfaces.

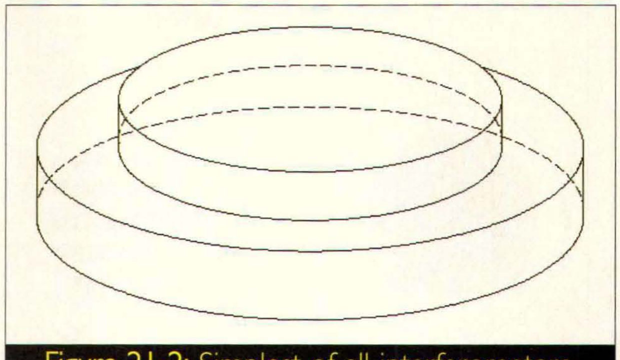

Figure 21-2: Simplest of all interferometers.

Depending on the type of coatings on the surface, many laser mirrors can be checked in this way. Most standard laser mirrors use a thin multilayer dielectric coating (usually an evaporated or sputtered metal), but because the coatings are so thin, it remains transparent to the majority of visible light.

If you look at these mirrors in white light, and gradually move them relative to your eye, you can see many different colors transmitted through them, or reflected from the coated surface, showing how some wavelengths can be transmitted (or reflected) by using either different coating thicknesses or else angle of incidence selection to filter out the different wavelengths. All mirror blanks (i.e., uncoated mirrors) are tested for flatness in this way before being coated.

The most common light source to view interference fringes is a sodium light, with its characteristic yellow coloring, but it can also be a darkroom safelight as used in photography. A darkroom light will give out a red colored light that, while not truly monochromatic, is close enough for our purpose. If you do not have a single color light source, then viewing the interference fringes under regular white light will be made difficult, but not impossible. Try using a photographic filter or colored film in front of a lamp, if you have nothing else available.

Figure 21-4 shows what the Fizeau interferometer reveals when used in a monochromatic light field. Here, the mirrors are depicted as being between the light source and the observer. Figure 21-4a shows two perfectly flat mirrors. The dark field covering the interface between the mirror surfaces indicates that all points on the mirrors are touching. The reflected wavefronts from the two surfaces overlap perfectly, leaving no interference bands. They are in what is called the 'zero order.'

If a slight tilt is imposed on the upper mirror, so that a slim wedge of air is introduced between them, then the dark field is broken into a series of straight parallel bands as seen in

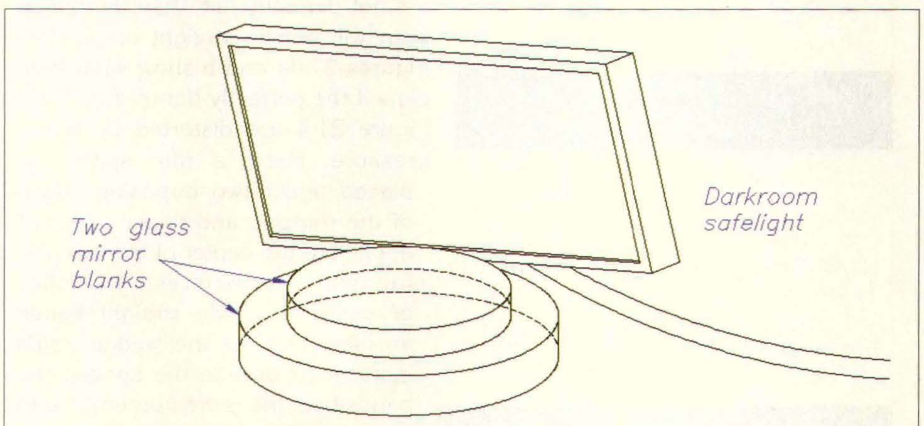

Figure 21-3: Simple set-up for viewing interference fringes.

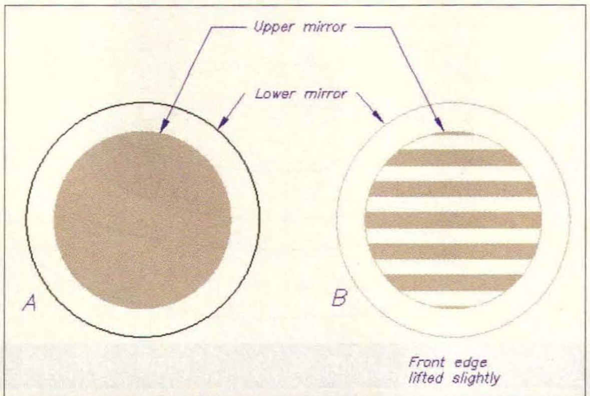

Figure 21-4: Two flat mirrors in a monochromatic light field.

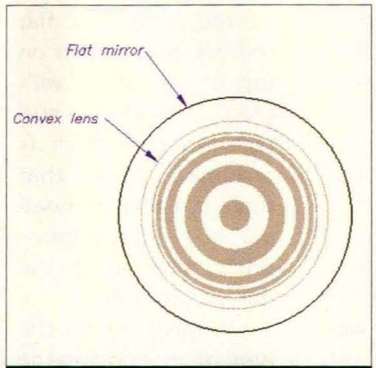

Figure 21-5: A spherical lens on top of a flat lower mirror.

Figure 21-4b. The alternate light and dark bands indicate that the two mirrors are flat, and that there is an airspace between them. The distance between the bands is dependent upon the thickness of the airspace, i.e., the magnitude of the tilt between the mirror faces. As the airspace angle is increased, the bands get narrower, and the separation between them becomes closer.

In a similar manner, if a convex (magnifying) lens is placed on a flat mirror, curved side down, the interference bands show a circular disposition as shown in Figure 21-5, with the bands growing wider as they get closer to the center. The reason the bands get wider near the center is due to the fact that as the surfaces of the lens and mirror become more nearly parallel, interference fringes become wider, as illustrated in the case of the flat mirrors mentioned above.

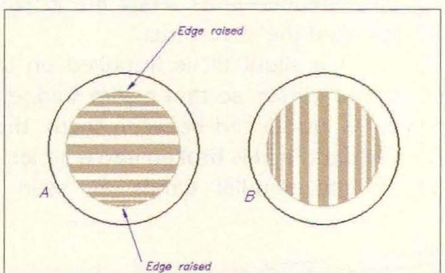

Figure 21-6: Flat mirror distorted by center pressure.

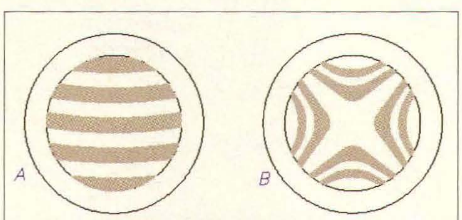

Figure 21-7: Example of a non-flat mirror.

A lens with a long focal length will show bands similar to those in the drawing; a shorter focal length lens will show a small center spot, with interference bands much closer to the center, and increasing very rapidly in frequency as you move away from the center. If a lens is placed on a form that has the same curvature as the lens, the reflected wavefronts will again overlap perfectly, and give a result similar to the flat mirror example shown in Figure 21-4a. Lenses for critical applications are tested this way.

If the flat mirrors in Figure 21-4 are not perfectly flat, then the bands seen will not be straight or parallel. Figures 21-6a and b show what happens if the perfectly flat mirrors from Figure 21-4 are distorted by finger pressure. Here, a thin spacer is placed under two opposing edges of the mirrors, and finger pressure applied to the center of the top mirror. Where the surfaces are parallel, or nearly so, wide straight bands are seen, but as the wedge angle increases closer to the spacer, the bands become more numerous and narrower. The curvature imposed by finger pressure produces a surface area that is closer to the lower mirror along the middle axis. As such, the mirror surface goes through a long curve that is almost parallel to the lower mirror along the middle axis. The curving sides of the upper mirror thus show a varying wedge angle, evidenced by the changing spacing of the interference bands in Figure 21-6a.

Rotating the viewing angle through 90 degrees will produce the interference pattern shown in Figure 21-6b. In raising the edges of the mirrors, it is only necessary to raise them by a small amount, say the thickness of a playing card or so. This method of measuring the form of a mirror surface is very accurate and sensitive, as you no doubt can see.

Mirror flatness is crucial to the proper operation of a laser. You will see later in this series, that wavefront distortion introduced by a non-flat mirror will also prevent the production of good holograms. Laser mirrors — and the mirrors used for holography — are normally made with degrees of flatness that vary from 1/4 wave to 1/10th wave. The flatter the surface, the more expensive the optic.

What these numbers mean is that the surface of the mirror in question will have a peak-to-peak flatness that can only be measured in terms of fractions of a wavelength of the light used to measure them. Thus, a mirror that has a flatness of 1/10th wave, let's say, at one wavelength, may have a flatness of 1/8th wave at a different wavelength. In a similar manner, the curvature of a lens can be described in terms of fit to an ideal surface.

When mirrors and lenses are specified, the wavelength of light used to measure the flatness or form is usually given. For example, Melles Griot (Irvine, CA) usually specifies flatness of their optics in terms of light at 546nM (yellow/green region of the visible spectrum). Optics typically run from 1/4 wave to 1/10th wave flatness for standard items. Other vendors may use a red HeNe laser as their standard (694.3nM) to specify flatness. Using the Melles Griot figures, at 546nM, a 1/10th wave optic would have a peak-to-peak non-flatness (for want of a better word) of about 55nM, measured over the surface of the optic. That's pretty flat!

The above description of the surface of an optic is very important to the optical engineer, who must decide the best compromise between the surface fit and the cost of the optic for a particular application.

In Figure 21-7, we see a couple of forms of distortion that can creep into a lens or mirror surface during manufacturing. During the polishing process, the mirror or lens blanks must be held very securely in order to get the correct surface figure required of the optic. If there is any tendency for the blanks to move, then the resultant polished surface will not be flat, but will exhibit unpredictable peaks and valleys.

In Figure 21-7a, the upper mirror shows some degree of radius, evidenced here by the curved interference bands. Further testing will show whether the surface is convex or concave. For instance, if finger pressure is applied to the center of the upper mirror, the interference bands will be seen to move. If the bands get wider under the center of pressure, it means the mirror surfaces are being forced closer to parallel, so the mirror must be concave.

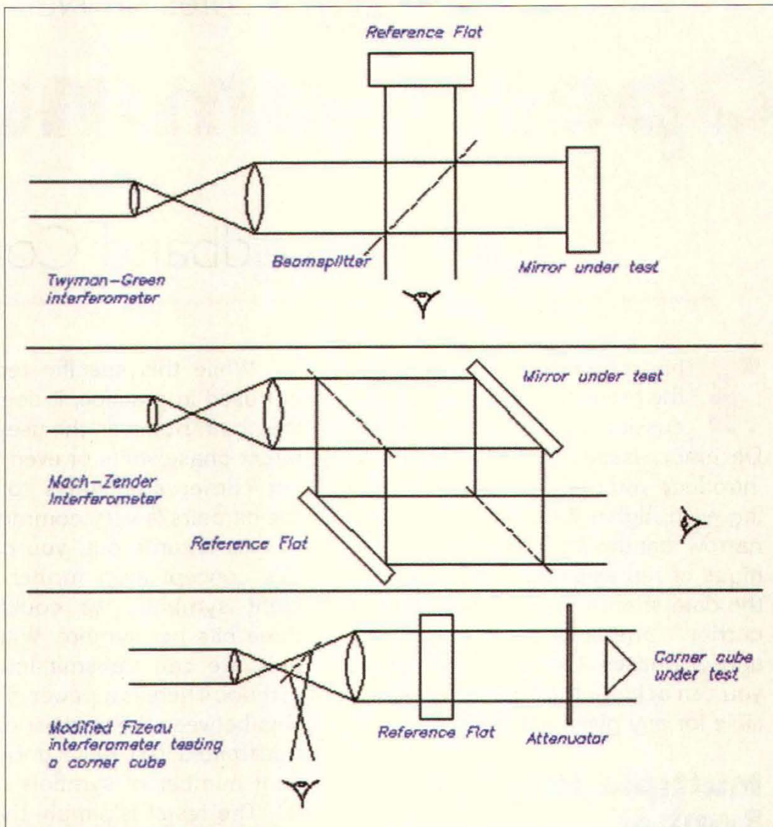

Figure 21-8: A few interferometer types.

Figure 21-7b shows a mirror whose surface is divided into four areas, each trying to cause some distortion or lensing effect on light passing through it. In this case, the combined distortion would be called astigmatic, and the optic would have preferential focusing effects on orthogonal axes, possibly two focal planes at slightly different distances from the lens.

These are just a couple of the many types of interference fringes that can show up using this simple set-up. This type of interferometer has also evolved into many others, each with its own advantages and particular applications. A few interferometer types are shown in Figure 21-8. I haven't room in this column to go into details about each one, so please bear with me.

If you have any questions on these, please email me at the address given below. I always answer all my emails, even though it sometimes takes me a while. So, if you have any questions about this column, or about optics and lasers in general, please write to me in care of this magazine, or at stanley.york@att.net. **NV**

The Latest in Networking and Wireless Technologies

Open Communication

Part 3: Broadband Communications

This month, we continue with the broadband modulation discussion I started back in the December issue. This time, I want to introduce you to the concept of sending even higher data rates through a narrow bandwidth by using a technique of representing multiple bits in the data stream by a mix of different carrier amplitudes, frequencies, and/or phases. Using this technique, you can achieve the highest rates possible for any given bandwidth.

Multiple Bits Per Symbol

I haven't used the term symbol yet, so let me define it. A symbol is one specific carrier state. It may be a specific frequency or phase position or even a specific amplitude. When transmitting binary data, we use one symbol per bit or one bit per symbol. In FSK, there are two symbols: a binary 0 is one frequency and a binary 1 is some other frequency. In BPSK, a binary 0 is 0° phase shift, while a binary 1 is 180° phase shift. Anyway, you get the idea.

We can expand upon that idea and say that we could use more than just two symbols to transmit more bits per symbol. For example, we could use four symbols to transmit pairs of bits (sometimes called dibits). Suppose that we used four discrete frequencies in a unique FSK scheme where one frequency or symbol represents each unique two-bit pair.

Frequency 1 = 00
Frequency 2 = 01
Frequency 3 = 10
Frequency 4 = 11

While this specific technique is not used in practice, it does illustrate the point. However, the use of four different phase shifts or even four different carrier amplitudes to represent the bit pairs is very common.

As it turns out, you can extend this concept even further. By using eight symbols, we could transmit three bits per symbol. With 16 symbols, we can transmit four bits per symbol. There is a power of 2 relationship between the number of bits to be transmitted (N) per symbol and the total number of symbols (S) or $S = 2^N$. The result is simply that you are going to be able to transmit more bits/Hz than with other methods. And the number of bits/Hz can be even further increased by combining two different types of symbols.

Popular Modulation Methods

There are several widely-used data modulation methods that transmit multiple symbols per bit time. These are QPSK, DQPSK, and QAM. Let's take a look at these methods.

QPSK — A very popular version of BPSK is called QPSK or quadrature phase shift keying. Figure 1 shows the modulator circuit. The serial binary data is fed into a two-bit shift register. Each bit of the pair of bits in the register modulates a separate balanced modulator. One balanced modulator receives the carrier signal represented by the mathematical expression $V\sin\theta$ which is just the trigonometric expression for a sinewave.

This carrier is shifted in phase by 90° to produce another sinewave, really called a cosine wave, designated $V\cos\theta$ which is the trig expression for a sinewave shifted in phase by 90°. The output of each balanced modulator is a BPSK signal, but one is shifted from the other by 90°.

These two signals are called the in-phase (I) and quadrature (Q) signals. The I and Q signals are then linearly added together to produce the QPSK output. What you get when you add two sinewaves of the same frequency and amplitude but different phases, is another sinewave of the same frequency, but with some intermediate phase. For example, adding sinewaves with phases of 0° and 90° produces a new sinewave with a 45° shift. Anyway, the table below shows the output phases you get with the different bit pairs.

00 = 45°
01 = 135°
11 = 225°
10 = 315°

This is usually shown graphically

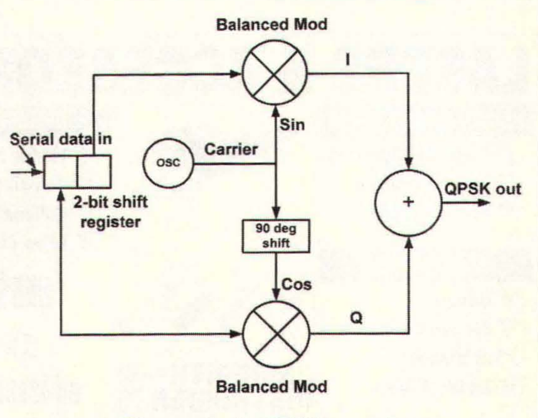

Figure 1. A QPSK modulator.

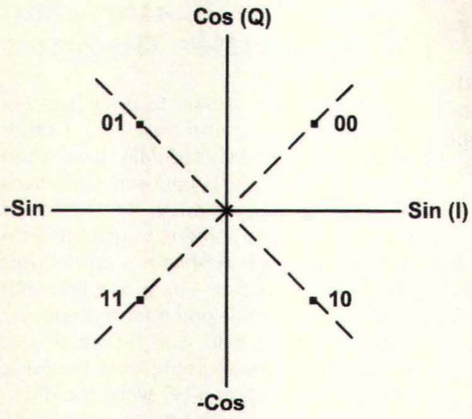

Figure 2. A constellation diagram for a QPSK modulator.

in Figure 2 in what is called a constellation diagram (see sidebar).

What you are really doing in QPSK is transmitting two separate BPSK signals simultaneously. By adding them together, you get one signal and the 90° shift between them allows you to separate them out at the receiver. QPSK is very spectrally-efficient. It can theoretically achieve a two bits/Hz rating.

DQPSK – Differential QPSK is simply a version of QPSK that uses the previously-transmitted signal phase as the reference for the current phase. As discussed in the previous installment of this article, this method does not require the complex carrier recovery needed in standard QPSK for demodulation. Also known as $\pi/4$ - DQPSK,

This method is used in time division multiple access (TDMA) digital cell phones. It permits transmitting digital voice data at 48.6 kbps in the 30 kHz cell phone channel. This gives an amazing 48.6/30 = 1.62 bits/Hz rating even with the noise and signal fading associated with wireless transmissions.

8-PSK and Beyond – You can take the basic principle of QPSK and extend it to use even more phase increments. In 8-PSK, you use eight phase symbols equally spaced 45°. See the constellation diagram in Figure 3. This gives you three bits/Hz theoretical efficiency. With 16-PSK, you use 16 phase shifts spaced 22.5°. This gives you a maximum of four bits/Hz, in theory. All of these methods provide major increases in the data rate for a given bandwidth. The downside is that it gets progressively more difficult to detect small phase changes at the receiver and noise introduces phase shifts that result in bit errors. The practical limit for this method is about 16-PSK.

QAM – QAM stands for quadrature amplitude modulation. It is a combination of both PSK and ASK. Also known as amplitude phase keying (APK), QAM uses combinations of signal amplitude and phase symbols to represent multiple bits. For example, in 8-QAM there are eight symbols, two different amplitude levels, and four different phase positions. See the constellation diagram in Figure 4A. 16-QAM encodes four bits per symbol with four different amplitudes and four different phase positions. An alternate method uses three amplitude levels along with 12 phase positions to provide four bits per symbol. See Figure 4B that shows the constellation diagram. 8-QAM and 16-QAM give theoretical maximum efficiencies of three bits/Hz and four bits/Hz, respectively. Again, while you can achieve amazing speeds in limited bandwidths, QAM is more noise-sensitive than any of the PSK modulation methods. Greater errors are potentially possible if the signal-to-noise ratio is not large enough.

QAM is very widely used in data communications. For example, it is the modulation method used in common dial-up computer modems. How else do you think that you can transmit up to 56 kbps (actually only 53 kbps max) in a four-kHz bandwidth voice telephone line? 64-QAM is widely used in cable TV systems to transmit video digitally. Using the 6-MHz bandwidth channels on the cable, they can achieve a data rate of 27 mbps. Such a high rate is needed to transmit video that has been digitized. Some cable systems use 256-QAM to get 38 mbps in each 6-MHz wide channel.

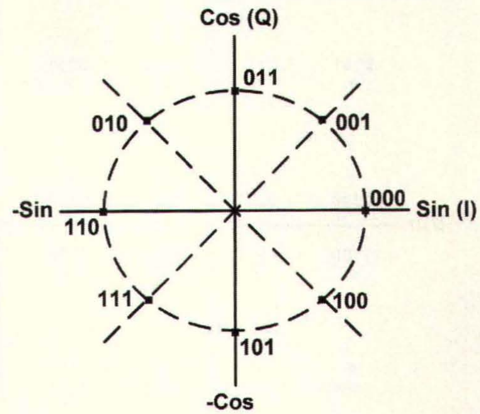

Figure 3. A constellation diagram for 8-PSK modulation.

What's Noise Got to Do With It?

All during this discussion, you probably noticed that I kept stating the theoretical maximum bit rate for a given bandwidth. That maximum rate is rarely achieved in practice. Why? Noise.

Speed and bandwidth are directly related and you can see how that relationship works. But what is not clear at all is that noise in the system also greatly affects the data rate. So let's look at that. But first, what is noise?

Noise is any random amplitude and/or frequency/phase variations that occur in all communications systems. These variations add to any signal being transmitted and partially obscure the data, even obliterating it on occasion. Noise comes from two

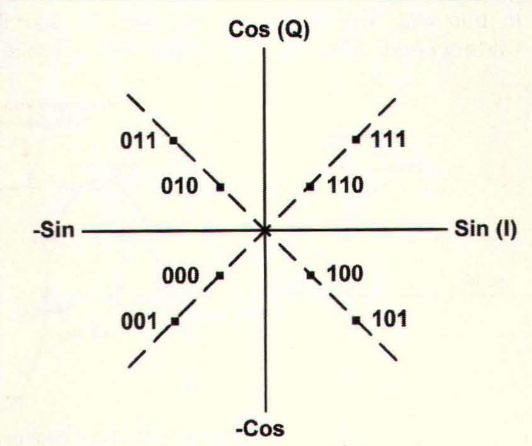

Figure 4A. A constellation diagram for 8-QAM.

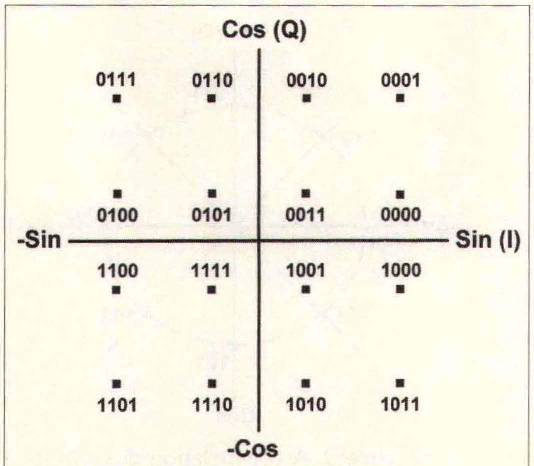

Figure 4B. A constellation diagram for 16-QAM.

sources: external and internal. External noise is produced by atmospheric effects like lightning and rays from the sun and stars. External noise is also generated by other electrical apparatus like motors and relays turning off and on, auto ignitions, fluorescent lights, and anything else that creates transients rich in harmonics that radiate.

Internal noise occurs in all resistors and transistors. It is caused by thermal agitation. The heat in any component causes random motion of the electrons that creates random noise. Such noise can be reduced by using low-noise components, but it can never be eliminated completely. So, in any communications system, we put up with the noise since we usually have little or no control over it. But what we can do is make the signal being transmitted have a much greater power than the noise power. In this way, the signal-to-noise ratio (abbreviated SNR or S/N) will be favorable to recovering the signal.

Since noise is both random amplitude and frequency variations, it affects all types of modulation. However, since FSK and PSK have a constant amplitude and the data is contained in the frequency or phase, the receivers can clip off amplitude variations without disturbing the data content. Therefore, FSK and PSK are far more immune to noise than any type of amplitude modulation like ASK, OOK, or QAM. But while FSK and PSK modulation is preferred, there are still many applications with amplitude modulation variants (such as QAM) used if the S/N is great enough.

The basic law relating bandwidth and noise-to-data rate is the Shannon-Hartley Law that expressed mathematically is:

$$C = 3.32B\log(1 + S/N)$$

C is the channel capacity or rather the data rate in bits per second.
B is the bandwidth in Hz.
S is the signal power.
N is the noise power.
Log is the common logarithm or base 10 log.

As you can see from this formula, the data rate is directly proportional to bandwidth and the logarithm of the S/N. Since bandwidth is usually specified by the FCC, the speed is limited by that bandwidth. Luckily, multi-symbol modulation methods help us to overcome this limitation. And we do have control over the S/N since we can set the signal power to a level that more than adequately overcomes the noise.

So, now you know. The speed vs. bandwidth relationship is so common in electronics that it is hard to escape it. Understanding it certainly explains many things. It especially brings home the importance of radio spectrum space that is more than just a precious natural resource. Anything we can do to squeeze more speed in a given bandwidth is worthwhile. Just don't forget that the noise level also plays an important role in setting the upper speed limit for a given bandwidth. As in all electronic engineering, the design trade-offs between power, speed, bandwidth and noise are the hardest. **NV**

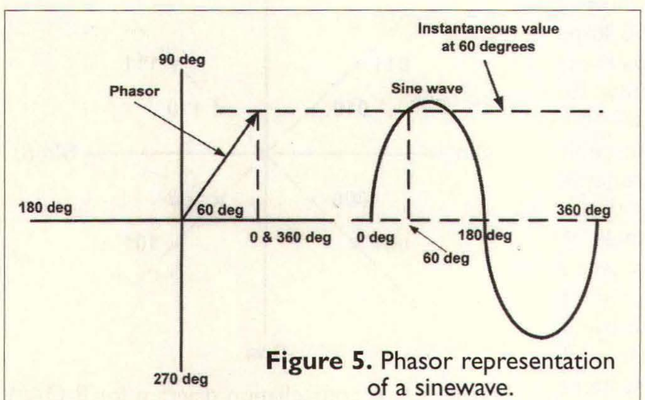

Figure 5. Phasor representation of a sinewave.

Sinewaves, Phasors, and Constellation Diagrams

Sinewaves are a pain to draw and are difficult to compare to other sinewaves. This is especially true when trying to distinguish between sinewaves of the same frequency, but different phase shifts. The solution to this problem is to use phasors. A phasor — sometimes also called a vector — is just a line with an arrowhead on it pointing in a specific direction on an axis. See Figure 5. The length of the phasor represents the peak value of the sinewave (V) while the direction the phasor is pointing represents the phase position of the sinewave.

If you drop a line from the tip of the phasor perpendicular (90° angle) to the horizontal axis, you form a right triangle. The perpendicular line length represents the instantaneous voltage amplitude (v) of a sinewave at some specific phase position or angle θ or stated mathematically, $v = V\sin\theta$. The phasor is assumed to be rotating in the counter-clockwise position. As it does, the perpendicular line length traces out a sinewave over the 360° rotation. One complete rotation represents one cycle of a sinewave.

The phasor is a great way to visualize sinewaves as you can tell at a glance where they are in their phase transition. This method is widely used to indicate the phase of a sinewave in various types of phase shift keying. However, only the position of the point of the phasor arrow is indicated on the axis. The actual phasor is not drawn as you can assume that a line is drawn from the point of the arrow to the center of the axis. This greatly simplifies the drawing. Multiple points or dots shown on the axis indicate that a sinewave is changing phases. Such a diagram is known as a constellation diagram and is widely used to show different types of phase and amplitude-phase modulation.

Basics For Beginners

Just for Starters

A Close-up Look at Desoldering

Last month, we took a look at some soldering basics. Now, we find we have the wrong component on the board. So, let's take it off.

Desoldering is one of the more difficult arts to learn in this business. It is the area where we most often damage the item we are working on. The key to desoldering is heat control. You want to apply enough heat to get the job done. But, you must remove the heat quickly to avoid damage. Tremendous strides have been made in the manufacturing process for printed circuit boards that make them much harder to damage. In the 50s and 60s, it was extremely difficult to remove a part without damage to the board. Fortunately today, we have a lot more latitude during the learning process.

I can give you a few tips on getting started. However, "practice makes perfect" definitely applies in this area. Photo 1 shows the use of a wick-type solder remover. The wick is placed under the tip of the iron, leaving an inch or so of fresh wick sticking out and, as the solder is melted, you pull the wick back and it will absorb the excess solder.

This needs to be done very quickly because once the solder is hot enough to melt, the heat being applied is also hot enough to damage the board. You may have to do this operation in several stages, allowing the board to cool a bit (20 to 30 seconds) in between each application of heat. Experience will give you a feel for this and you will get where you can move faster and allow less cooling time. Cut off the used part of the wick when it becomes saturated and unwieldy.

Once you have removed as much of the old solder as you can, the lead will very likely slip out with no heat applied. If needed, you can apply heat to the joint and pull the lead back through the board. If the lead is bent over, you can use desoldering tools such as the Mouser #384-1018 desoldering kit provides. For 25 years, I got by without the tool set, but they are worth having. There are differences in the efficacy of the various brands and styles of wick. The wick sold by RadioShack is a decent, garden variety wick. However, you might want to try some of the other brands and sizes.

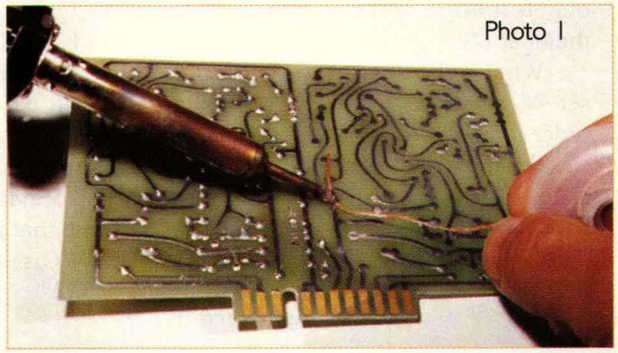

Photo 1

There are differences in the chemicals applied to enhance the action of the wick. Mouser carries wick by Techspray and Soder-Wick. The Soder-Wick "no clean" series is my favorite. I generally buy the .080 in their "60 series" (Mouser #5878-60-3-5). This is a good size for general hobby work and is extremely efficient. Techspray also makes a wick similar to this (Mouser #577-1816-5F) and it is most likely comparable in action. I just got started with Soder-Wick and have stayed with them.

As with most other things in this world, you probably should try several sizes, brands, and styles to find the one that works best for your application. I drive a Dodge pickup with fuzzy dice hanging from the mirror. Some people would swear that Ford is the only way to go and that fuzzy dice only show my age. I have found that clipping a lead on the component side of the board (Photo 2) as near the component being removed as possible allows me to deal with each lead as a separate entity.

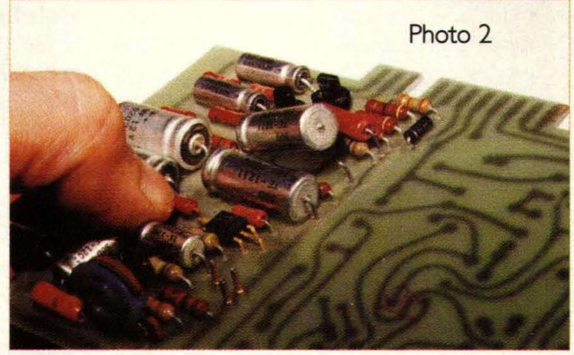

Photo 2

One of the strange things about desoldering is that, if the old solder doesn't want to melt, you can apply just a touch of new solder and it will cause the old to melt. In the event you find that some old solder doesn't want to melt, even though you are applying what appears to be adequate heat, take your roll of solder and act as if you were soldering rather than desoldering. After you get the old solder to melt, it will solidify again as soon as you remove the heat. However, you will find that it will liquefy easily with the next application of heat, at which time, you use your wick to remove it.

Remember that practice makes perfect. Just be sure to start your practice on things that don't matter.

Next month, we will have some "random thoughts." Little bits and pieces of unrelated information that might come in handy. **NV**

QUESTIONS

I bought a system from Quantex Microsystems three years ago. The system works well or did. The company — who is now defunct — told me the system came with an NEC 19" Trinitron monitor. The monitor does not get a picture. I called NEC and they told me that not only is it not a Trinitron, but it is not theirs at all.

What is the possibility I can get a set of schematics for this thing in order to fix it? I believe it's a relay.

When I shake the mouse to wake it up, I get a click. The green power light's on, but no click. It's not the card, it tested okay.

#2031 **Stu Weinstein via Internet**

I have an aftermarket CD player in my car that came with an infrared (IR) remote that mounts on the steering wheel. The remote needs to mount on the right side of the steering wheel in order for the CD player to be able to receive the IR signal. However, in my car, the right side of the steering wheel has the cruise control buttons. Therefore, I need to mount it on the left side.

I need a wired IR repeater in which I can mount the IR sensor on the left dash, run a wire to the center console, and have an IR LED retransmit the signal to the radio. (RadioShack has a device for use at home that does this via RF, but I need this to use a wire.)

#2032 **Adam Huber via Internet**

A PC motherboard comes with IrDA connection pins on it. I am looking for a general, cheap, and simple IrDA adaptor circuit (schematic) which I can connect to the PC motherboard connectors to receive remote control signals and also to communicate between the IrDA devices.

There are some circuits on the Internet for PC remote control which use the PC's serial port instead of IrDA pins. The drawback of this type of serial port circuit is on the software side, which makes a load on the CPU, due to continuous checks for an IR signal present or not.

#2033 **Kintesh Patel Columbus, OH**

The camcorder that I have is a Sony CCD-TRV16. It is an analog unit, but does have a connector identified as "LANC" that has digital pulses coming out when in the playback mode. The mating connector is a miniature tip-ring-sleeve plug (miniature three-circuit phone plug). Is there any information on what these pulses are and how they can be used? Can pulses be sent in to perform functions?

Sony sold a piece of equipment that could be used for editing and other uses, but it costs as much as the camcorder. Any information about these pulses or equipment that can be built or purchased to work with this for editing and remote control will be most helpful.

#2034 **Dale Blackwell Brazil, IN**

I'm interested in producing power from a wind-driven generator. Should I use a large 32-volt DC Baldor motor that I salvaged from a golf cart? This motor is a shunt-type DC with an extra set of brushes (four brushes). The extra set must be for reverse? I have spun the motor with a belt and another motor, but it doesn't produce electricity. I have disassembled the motor and it's possible to isolate the field from the armature. Is there a circuit to excite

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ANSWER INFO

- Include the question number that appears directly below the question you are responding to.
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To be considered

All questions should relate to one or more of the following:

1) Circuit Design
2) Electronic Theory
3) Problem Solving
4) Other Similar Topics

Information/Restrictions

- No questions will be accepted that offer equipment for sale or equipment wanted to buy.
- Selected questions will be printed one time on a space available basis.
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Helpful Hints

- Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
- Write legibly (or type). If we can't read it, we'll throw it away.
- Include your Name, Address, Phone Number, and Email. Only your name, city, and state will be published with the question, but we may need to contact you.

the field and turn this motor into a brute-force, blade-driven generator?
#2035 Gordon McKittrick
Havre, MT

Is there anyone that can tell me where I can find a MM5369 60 Hz timebase chip? It seems to be obsolete and very hard to find. If this chip is unavailable is there a direct replacement for it?
#2036 Lexpro, via Internet

Has anyone interfaced a PIC with a standard ISA Ethernet network interface card so that no PC is involved?

I have just been given a box of assorted out-of-date PC hardware and there are a few ISA NICs. I had an idea that I could plug them into little roving gadgets. The whole thing would look something like an octopus (the body would hold the hub) on rollerskates.
#2037 Mr. Bwtz, via Internet

I'm looking for a device called a "Solar Dancer" — a linear motor that is used in point-of-purchase advertising.

It's plastic and approximately 1" x 2" x 3". It has a pendulum that is expended past the pivot to which a sign is affixed. The unit is self-starting when exposed to a bright light and will wave a sign with the advertiser's message. I could use a dozen(?), maybe more if my application catches on. Or they can be battery powered? Does someone know of a source, have a schematic (for sale), or have the gizmo in a kit?
#2038 Rick Otto, via Internet

Can anyone think of a way to take serial data into a PIC and convert it from logic pulses to audio (serial data) tones to be transmitted via amateur radio, say using two PICs? I found a modem chip (MX614), but it is very hard to purchase. I thought with using two PICs, I could eliminate the modem, but I can't seem to think of a way.
#2039 Chris, via Internet

Is there a simple or cheap way to mount a PC camera to a microscope? I would like to take advantage of fine adjustments of the microscope (focus and manual stage) for the purpose of viewing watches and other small mechanical objects. Is there a way to modify the eyepiece for this purpose?
#20310 Chuck, via Internet

Can anyone recommend a good PCB .cad file format viewer? I tried the Unisoft View free version, but it's too limited to view the .cad file I'd like.
#20311 Bob, via Internet

ANSWERS

[12025 - DEC. 2003]

I fly radio-controlled model gliders made from foam so we can combat them (i.e., literally try to knock each other out of the sky)! I have seen ideas that use infrared technology to have an IR "gun" on the nose of the fuselage and a sensor that counts the hits on the "enemies" rear or cockpit. Are there bits and pieces that would let me put together such a setup?

The difficulty with most of these units is that many of the beams emitted have an extremely limited effective range. For instance, ultrasonic beams tend to spread out — a beam that starts out only as wide as two centimeters, with spread out to wider than one meter after travelling three meters (and the signal needs to travel another three meters to get back). At this rate, the signal would be too wide and too weak to do anything. Also, while a flat surface pointed directly back at the "emitter" will send its reflection back at the emitter, an angled or curved surface will deflect the emitted beam off to where you don't have a detector.

My best suggestion would be to place some "targets" in the other plane, so that when you hit it with a beam, it registers "I've been hit!" Look at **www.omega.com** for sensors and free handbooks and see what's possible!

Thomas Ng
San Jose, CA

[12028 - DEC. 2003]

I have a "solid-state automatic charger for deep cycle 12-volt batteries. I do not measure any voltage at the terminals, but when connected to a battery, it turns on and charges. I noticed a small circuit board with a transistor and three diodes. What is the principle of operation of this charger?

The circuit is likely an SCR being used as a switch and a power rectifier. The SCR connects the AC power to the battery-. It is turned on with a resistor from battery+ to the SCR's gate. When the battery voltage reaches a zener's voltage, a small transistor shunts the gate current to the SCR's cathode, turning it off.

A voltmeter does not pull enough current to keep the SCR on. This circuit is often found on lawn tractor-type engines, too.

G. E. Brown, via Internet

[12027 - DEC. 2003]

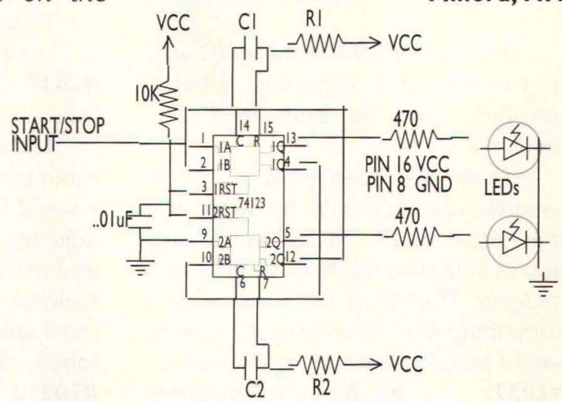
I was challenged by the question of making a free-running clock using (two) 74122s and all of the necessary resistors and caps to set the timing, and LEDs to indicate the pulse at the out of each of the 122s. I have read, seen, and made the same free runner using a 555 timer and two resistors and a cap to set the pulse timing with an LED to indicate the pulse, with no problem. Any suggestions on the wire-up?

This answer uses the 74HC123, a dual of the 74122. If you have 74122s, the wiring is the same, but the pin numbers are different.

The time between pulses is set by C1 and R1. The time is given by: Tw=.45RC. The pulse width of the second one shot is set by C2 and R2 using the same formula. For long times, I recommend low-voltage ceramic capacitors, values up to 1uF in X7R material can be found.

The period of oscillation is T1 + T2. The 10K resistor and .01 capacitor insure that the system starts up at power on with both LEDs not lit. The oscillator is started by bringing the start/stop input low, and it must stay low as long as the oscillator is running.

Russell Kincaid
Milford, NH



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