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Everything For Electronics

Nuts & Volts

January 2003

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Contents

COLUMNS

Everything For Electronics
Nuts & Volts
Vol. 24 No. 1

PROJECTS

DEPARTMENTS

Nuts & Volts (ISSN 1528-9885) is published monthly for $24.95 per year by T & L Publications, Inc., 430 Princeland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: Send address changes to **Nuts & Volts, 430 Princeland Court, Corona, CA 92879-1300.**

Reader Feedback

Dear Nuts & Volts:

I am a college professor whose research area is the neural control of locomotion (walking), and I am also becoming interested in Robotics as a research tool, and as a hobby. I have finally gotten a chance to look through your Robotics Supplement #1, which I somehow received even though I'm not currently subscribed to *Nuts & Volts*. I found it very informative and enjoyable; the best robotics magazine for robotics beginners (like me) that I have seen.

Carl Spirito, Ph.D.
Portland, ME

Dear Nuts & Volts:

Wow! I subscribed at just the right time. For the past few years, I have begged, borrowed, or stolen copies of your magazine. But a month or so ago, I finally broke down and ordered a multi-year subscription. What a nice magazine.

I would like to take a minute and comment on an article in the Nov. 2002 issue called "A MIDI Christmas." This thing has more potential than an atomic bomb! I never thought I would see such a power-packed, practical project in any subscription magazine. I deal with show controllers a lot that cost in excess of $3,000.00 each and here you come with one that is practically free. I contacted the author by email and have really been treated well as they are eager to help and promote their project. I am in the process of ordering some prototype controller boards now and plan to incorporate this design into museum displays. I just wanted to say thank you for having the insight to run an article on a very practical project and hats off to the designers for being willing to share it with us.

Tim Driver
via Internet

Dear Nuts & Volts:

I am writing this letter to commend *Nuts & Volts* magazine and Bob Vun Kannon. I have all my *Nuts & Volts* magazines stacked on a shelf dated back to mid 1995, and I am sure I have older ones in the garage. Your magazine is great!

I have used the MicroLab BASIC compiler and PIC 1684 for many years and I love it. However, the PIC chips are just too pricey for simple circuits. The Atmel family of chips are less money, and I really wanted to use them instead of the MicroChip 16F84. Most of my projects are from simple to medium in complexity. I did a couple of projects in assembler, but BASIC just makes it so much easier, simpler, and quicker, so it was always the PIC.

Bob Vun Kannon's articles on the RVKBasic compiler was the key to move me over. I had a slow start since it is a little different than the MicroLab compiler I was used to, but I mailed the author and he was nice enough to point me in the right direction. Once I was rolling, I have been hooked on it ever since. I have done many switch and relay circuits and I am now working on an MP3 keyboard for our boat to control the PC in the cabin. My electric drill loves its new four-hour timer circuit and relay since I like to leave it plugged in and it gets a bit warm.

Please continue the support of the RVKBASIC in the future, the articles helped me get started, but it would be nice to see more AT90S1200 and 2313 projects. I love the PIC, but the price is too high and the 1200 with the internal OSC makes it attractive for simple projects at $2.00 and no XTAL and picofarad caps required. Thanks again and keep up the great work.

Mike Ramos
US Internet Technologies, Inc.

Dear Nuts & Volts:

Please consider changing to a "normal" size magazine layout. Oversize mags such as yours and *EETimes* have less value since they're too annoying to archive or even keep in a stack of "to be read" issues. I scan each issue of *N & V*, rip out articles, and dispose of the rest immediately.

If the mag was a standard size, I might be a little friendlier to it. I seriously questioned my last renewal — partly due to weak content and partly due to the annoying size.

Jim Boyd
via Internet

Editor's Note: Well Jim ... ask and you shall receive! Beginning with this issue, Nuts & Volts will now be a regular size magazine. Plus, we've added three new columns, put together a new projects section complete with skill-level ratings, and added other new features, as well. Check it out and enjoy!

Published Monthly By
T & L Publications, Inc.
430 Princeland Court
Corona, CA 92879-1300
(909) 371-8497
FAX **(909) 371-3052**
editor@nutsvolts.com
www.nutsvolts.com

Subscription Order ONLY Line
1-800-783-4624

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802.11b Wireless LAN Only
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Communication Protocol: HTTP, FTP, TCP/IP, UDP, ARP, ICMP, BOOTP, RARP, DHCP, PPPoE
System Requirements for IP View
CPU - Pentium III, 450 MHz or above
Memory - 28 MB (256 MB recommended)
VGA Card - 800 x 600 or above
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Win 98
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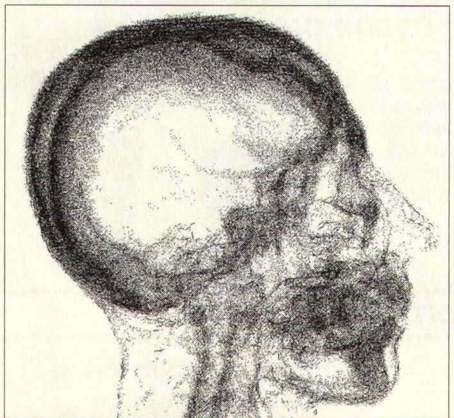
by Jeff Eckert

TechKnowledgey 2003

Events, Advances, and News From The Electronics World

Advanced Technologies

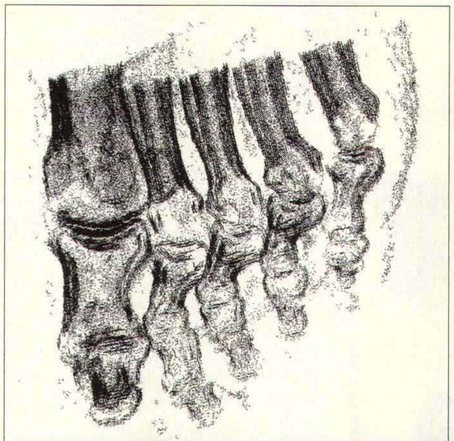
Ancient Technique Transforms Modern Medical Imaging



This image of a human cranium was created by converting computerized tomography (CT) scan data into dots.

Thousands of years ago, cave dwellers and other primitive artists used the process of "stippling" to create drawings on walls, eating utensils, and so on. In the modern version — generally known as "pointillism" — an artist (often equally primitive) uses essentially the same technique by applying dots of paint or ink to simulate light and dark gradations to form an image.

In an interesting digital adaptation of the process, engineers at Purdue University (**www.purdue.edu**) have come up with software that applies stippling to 3-D images generated by technologies such as computerized tomography (CT) and magnetic resonance imaging (MRI).



This picture of a human foot was created by applying a stippling effect to data from CT scans. Courtesy of Purdue University School of Electrical and Computer Engineering.

The software allows the technician to rotate the 3-D image, zoom in or out, and otherwise manipulate it to focus on specific portions, thereby obtaining a highly valuable preview in a very short time. Afterward, a more time-consuming process can be applied to obtain a higher quality image.

According to David Ebert, an associate professor at Purdue, "More conventional imaging methods of, say, a CT scan of a person's head require slower processing techniques, which means either you have to do a lot of processing or it takes a while to generate an image. We can have a CT rendering of a person's internal organs in real time, where the organs are represented as a series of small points."

The software is not yet available as a commercial product, but it should be ready for commercialization soon.

Atomic Clock Accuracy Improved

All clocks operate by counting the frequency of some sort of event (the swing of a pendulum, the AC powerline frequency, the movement of the sun, and so on). Atomic clocks are the most accurate, being based on the transition time of atoms as they move back and forth between two energy levels. This works because every isolated atom of a particular element is exactly the same as every other atom of that element, no matter where you go in the universe. However, even atomic clocks have not been totally free of timing errors.

Because the atoms they count traditionally have been contained within a glass vacuum chamber, and because the atoms occasionally collide with the chamber walls, the internal "ticking" of atomic clocks is not absolutely consistent. But a team of physicists and engineers at NASA's Jet Propulsion Laboratory (**www.jpl.nasa.gov**) have come up with a solution.

In a new version of the atomic clock, the atoms (mercury ions, actually) are contained not by a glass wall, but by an applied electric force field (called an ion trap), thus reducing the error factor to approximately 10,000 times less than existing devices.

The result is a clock that should provide accuracy to within one minute per 10 billion years. The good news is that this increased accuracy will be helpful for interplanetary space travel, where tiny timing disparities can dramatically affect spacecraft navigation. The bad news is that you will have even less of an excuse for being late to work.

Computers and Networking

New 128-Processor Server

Software engineer Daria Dooling examines a wafer of IBM Power4 chips. Each chip contains 174 million transistors and contains two high-speed processors, a system switch, memory, and I/O functions. Information flows between the memory and processor at nearly 125 GB/second, which is the equivalent of transferring 25 full-length DVD movies per second.
Photo courtesy of International Business Machines Corporation. Unauthorized use not permitted.

If you recall the legendary chess match between the IBM "Deep Blue" supercomputer and Garry Kasparov, you may find it interesting that IBM (**www.ibm.com**) has released an upgraded version of the famous machine for general consumption. IBM's eServer p655, powered by 128 of the company's POWER4™ processors per frame, offers peak processing power of 0.5 trillion operations per second in each frame. Versions are available with four or eight processor building blocks.

The UNIX-based p655 is designed for scientific and technical computing, high-level business applications, and massively parallel processing in digital media and life sciences. According to IBM, a single p655 rack takes up less space than the six racks used by a Hewlett-Packard rx5670 system with the same number of processors. The entry-level price for the p655 is $72,899.00.

In recent times, IBM appears to have regained its leadership position in supercomputing. Among the various machines included in the "Top 500 List of Supercomputers," IBM has a total of 93,074 TFLOPS of power online, which accounts for about 31% of the total processing power on the list. Hewlett-Packard, by the way, is second, with 64,827 TFLOPS.

"TOP500" List of Supercomputers Released

Since 1993, the Top 500 Supercomputer Sites (TOP500) organization has been compiling a list of the world's 500 fastest supercomputer installations "to provide a reliable basis for tracking and detecting trends in high-performance computing." Twice a year, a list of the sites operating the 500 most powerful computer systems is assembled and released. According to the latest version, released last November, NEC's "Earth Simulator," located in Japan, is the unchallenged king of the heap, at 35,870 TFLOPS, followed by two segments of the ASCI Q machine operated by Los Alamos Labs, with >7 TFLOPS each. For a look at the complete list, visit **aww.top500.org/list/2002/11/**.

Defense Against Pop-Ups

If you do a significant amount of Internet surfing, you are certain to be increasingly annoyed by pop-up windows aimed at selling you unwanted junk, steering you to other URLs, and otherwise intruding on your WWW experience. If so, you may want to try WebWasher®, a utility that can be set to filter out your choice of pop-ups, scripts, advertising banners, cookies, and other items that you would rather not encounter. The product, distributed by WebWasher.com AG, originated in the Siemens Computer Systems Development Division, based on an idea put forward during an internal innovation workshop.

The WebWasher Content Security Management (CSM) suite — created for enterprise-wide use — is billed as the first security solution that allows central administration and filtering of all web, email, and FTP traffic at the Internet gateway. The suite includes Internet access management, web content filtering, virus and malicious code protection, email filtering, and reporting functions to eliminate security risks deriving from the Internet. The price for this deluxe version starts at $29.00 per license for a single user and drops to $19.00 per license for 25 or more users. Potential buyers can download a 30-day trial version at no cost.

The WebWasher Client version for use on individual computers is available at no charge for home and educational use, and the company claims that it is already in use by five million individuals worldwide. It is available for Windows 95/98/2000/NT, Mac OS 8.1, and later, and Linux operating systems, making it highly versatile. To try it out, log onto **www.webwasher.com/en/products/wwash/download.htm** and follow the directions. (There is also a German-language page accessible from **www.webwasher.com**, if that is more convenient for you.)

Circuits and Devices

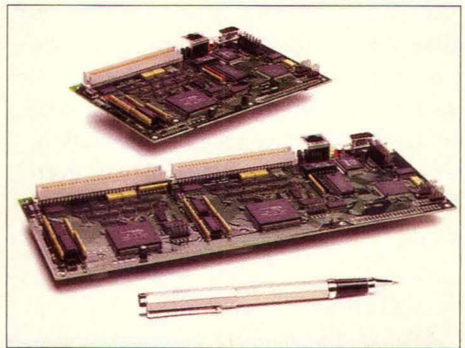
Math Learning Tool Introduced

For students who need to improve their math skills (or perhaps just cheat more effectively), Casio Computer Corp. (**www.casio.com**) is introducing the new ClassPad 300. The device allows the user to input and display expressions as they appear in a textbook. Factorization of expressions, calculation of limit values of functions, and other operations can be performed, with the results shown on a 160 x 240 dot LCD touch screen. The device includes tools for 3-D graphing and drawing geometric figures, and the user interface operates via a pull-down menu aimed at simplifying complex operations. The ClassPad 300 also supports drag and drop, copy and paste, and other pen-based operations that help to minimize keystrokes.

Main features include Casio's "computer algebra system" (CAS) natural display that allows input of fractions, differentials, integrals, ? calculations, lim calculations, and other expressions in the same format as that used in mathematics texts; a function conversion operation; and presentation software that allows screen shots to be played back in slide show format. Hardware includes a flash ROM (500 kB user area, 4 MB add-in area) and a USB cable for data transfer. It weighs only about 10 oz. (280 g) and operates on four AAA batteries. No price information was available.

Ethernet-Compatible Motion Controllers

The DMC-21x2 and DMC-21x3 Ethernet motion controllers, from Galil Motion Controls (**www.galilmc.com**), are intended to be used in cost-sensitive and space-sensitive applications. The units are available in one-axis through eight-axis versions and can be configured for control of step or servo motors to address any combination of axes.



Ethernet-compatible motion controllers drive steppers and servo motors in up to eight axes.
Photo courtesy of Galil Motion Controls.

The card-level controller measures just 4.25 x 7.0 inches (10.8 x 17.8 cm) for one-axis through four-axis models, and 4.25 x 10.75 inches (10.8 x 27.3 cm) for five-axis through eight-axis operation. Any mode of motion can be programmed, including linear and circular interpolation, contouring, electronic gearing, and ecam. Programming the DMC-21x2 is via two-letter, intuitive commands and a set of software tools such as WSDK for servo tuning and analysis, and the ActiveX Tool Kit for Visual Basic users.

The DMC-21x2 uses a 100-pin high-density connector for each set of four axes and requires Galil's Cable-

100 between the controller and ICM-2900 interconnect module. The DMC-21x3 uses a 96-pin DIN connector and does not require a cable between the controller and associated interconnect boards.

Special interconnect boards mount directly on top of the DMC-21x3 and are available with on-board drives for stepper motors, servo motors, or D-type connectors for interface to other motors and drives. Technical features include 10Base-T connectivity, an RS232 port (up to 19.2 kb), Modus protocol support, up to 12 MHz encoder frequencies for servos and 3 MHz for steppers, multitasking for up to eight application programs, sinusoidal commutation for brushless servo motors, and many other capabilities. The units run $795.00 to $1,595.00 in single units, with substantial discounts in quantities of 100+.

Industry and the Profession

Software Piracy Prosecutions Continue

Convicted software pirate Lisa Chen was recently sentenced to nine years in prison for her crime and ordered to pay $11 million in restitution to Microsoft and Symantec. This concluded a case that began in November 2001 when Chen and several associates were arrested in Los Angeles County, CA, with nearly $100 million worth of bootleg software in their possession. The contraband included more than 600,000 copies of Microsoft's Office 2000 application software, the Windows XP operating system, and Symantec's Norton AntiVirus software. The packages, which apparently were smuggled in from Taiwan, were nearly exact duplicates of the real thing, down to the printed manuals, license agreements, bar codes, and shrink-wrap packaging. Reportedly, the arrest came after an 18-month undercover investigation by the US Customs Service and California officials.

Telecommunications Anniversary

In case no one has already brought it to your attention, this year marks the 80th anniversary of the invention of the television camera. It was the creation of Vladimir Zvorkyn, a Russian-born US citizen, who called his 1923 invention the Iconoscope. Vacuum tube technology was the rage at the time, and this was something of a natural extension of advancements occurring in radio tube applications. Broadcast television appeared a few years later, with the first transmissions made in England in 1927. The phenomenon spread to the US in 1930. In his defense, we must acknowledge that Zvorkyn could not have predicted that his technology would eventually degenerate into the cultural wasteland that we now call television. NV

by James L. Antonakos

Electronic Theories and Applications From A to Z

Let's Get Technical

Operational Amplifiers: Examining the Basic Configurations

This month, I am beginning a series of technical articles on a wide range of topics, from analog and digital electronics, to microprocessors and microcontrollers, computer arithmetic, networking, and computer science theory. Some of the future topics I will be examining are:

- A fiber-optic data communication system.
- Intel protected-mode architecture.
- Image analysis and recognition.
- A/D and D/A converter techniques and operation.
- Oscillator configurations.
- The I2C Bus.

These articles are intended to "whet the appetite" for a particular topic by examining its theory and actual application. The material will vary from basic to advanced, hopefully in a straightforward manner. I am beginning the series with an examination of several typical operational amplifier circuits.

Basic Operational Amplifier Configurations

There are five basic operational amplifier configurations. They are:

1. The buffer.
2. The non-inverting amplifier.
3. The inverting amplifier.
4. The adder (or mixer) amplifier.
5. The subtractor (or difference) amplifier.

Figure 1 shows the schematic of the buffer amplifier. This is the simplest amplifier configuration, as it requires no external components, just a direct short between the output and inverting input of the amplifier. The voltage gain of the amplifier, defined as the ratio of Vout over Vin, is exactly 1.0 for the buffer amplifier. The output voltage is the same as the input voltage.

What is the purpose of an amplifier whose gain is 1.0? Although there is no increase in signal voltage, the buffer provides impedance isolation between the input and the output. This means that the input sees a high impedance (the input resistance of the operational amplifier, which is typically 10s or 100s of millions of ohms) and the output sees a low resistance (around 50 ohms). Impedance isolation is useful when you want to eliminate the loading effects of one component or circuit on another. This is illustrated in Figure 2.

The two-resistor voltage divider shown in Figure 2(a) will produce eight volts across the 4K resistor when there is no load attached, but only 5.71 volts when the 2K load resistor is connected in parallel with the 4K resistor. This is because the parallel combination of the 4K and 2K resistors produces an equivalent resistance of 1,333 ohms. So, the 10-volt supply voltage is not dividing between 1K and 4K, but between 1K and 1,333 ohms, which is why we get slightly more than five volts, instead of the eight volts expected. The 2K resistor loads the circuit and changes its operation.

In Figure 2(b), the voltage across the 4K resistor is eight volts, as expected, and the voltage across the 2K load resistor on the output of the buffer is also eight volts. The buffer isolates the 2K load resistance from the 4K circuit resistor.

The high input impedance of the buffer does not resistively load the 4K resistor, allowing the voltage to divide properly. Then, as long as the load resistance on the buffer (2K in this case) is reasonable and the buffer can supply the required current, the load resistor will have the same voltage across it as the 4K resistor does. Using a load resistance that is too small will draw excessive current from the buffer and cause the output voltage to become unstable.

Figure 3 shows the other typical operational amplifier configurations. Note that all four configurations employ negative feedback (a resistor between the inverting input of the operational amplifier and the output). We make amplifiers using negative feedback and oscillators using positive feedback. Each configuration has some visual clues that help identify it. Consider the following:

- The input signal is applied to the non-inverting input in the non-

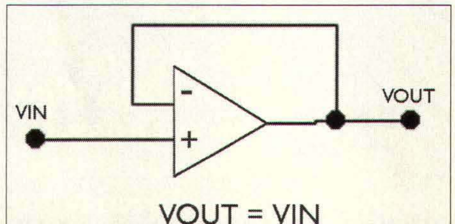


Figure 1: Buffer amplifier

inverting amplifier.

- The input signal is applied to the inverting input (through a resistor) in the inverting amplifier.
- All input signals are applied to the inverting input (through resistors) in the adder amplifier. This is like having two inverting amplifiers rolled into one. More than two input signals may be added or mixed together. Each signal requires its own input resistor.
- The input signals affect both inputs on the subtractor. The voltage controlling the inverting input is subtracted from the voltage controlling the non-inverting input.

The voltage gain, which is typically determined by the ratio of the feedback resistor to an input resistor, applies to both DC and AC signals.

Where Do The Equations Come From?

The equations relating Vin and Vout in Figures 1 and 3 were derived using simple DC circuit analysis techniques and by applying two important facts about the operational amplifier:

1. The inputs do not draw any current.
2. The differential input voltage is zero when negative feedback is used.

What do these two statements mean? First, the input impedance of an operational amplifier input is so high

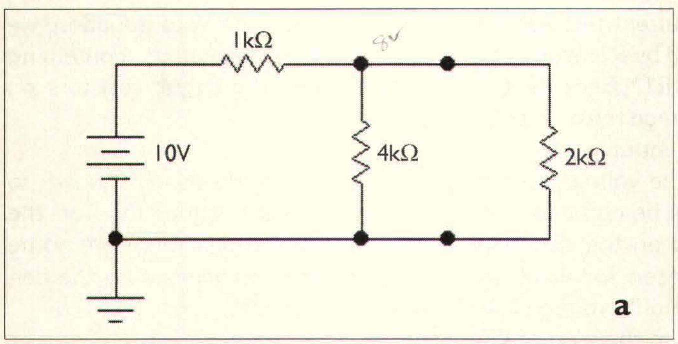
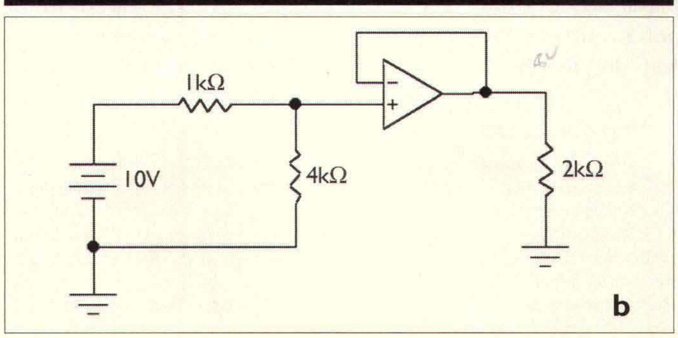


Figure 2: The effects of loading
(a) Voltage divider with 2K load resistor
(b) Buffered voltage divider with 2K load resistor



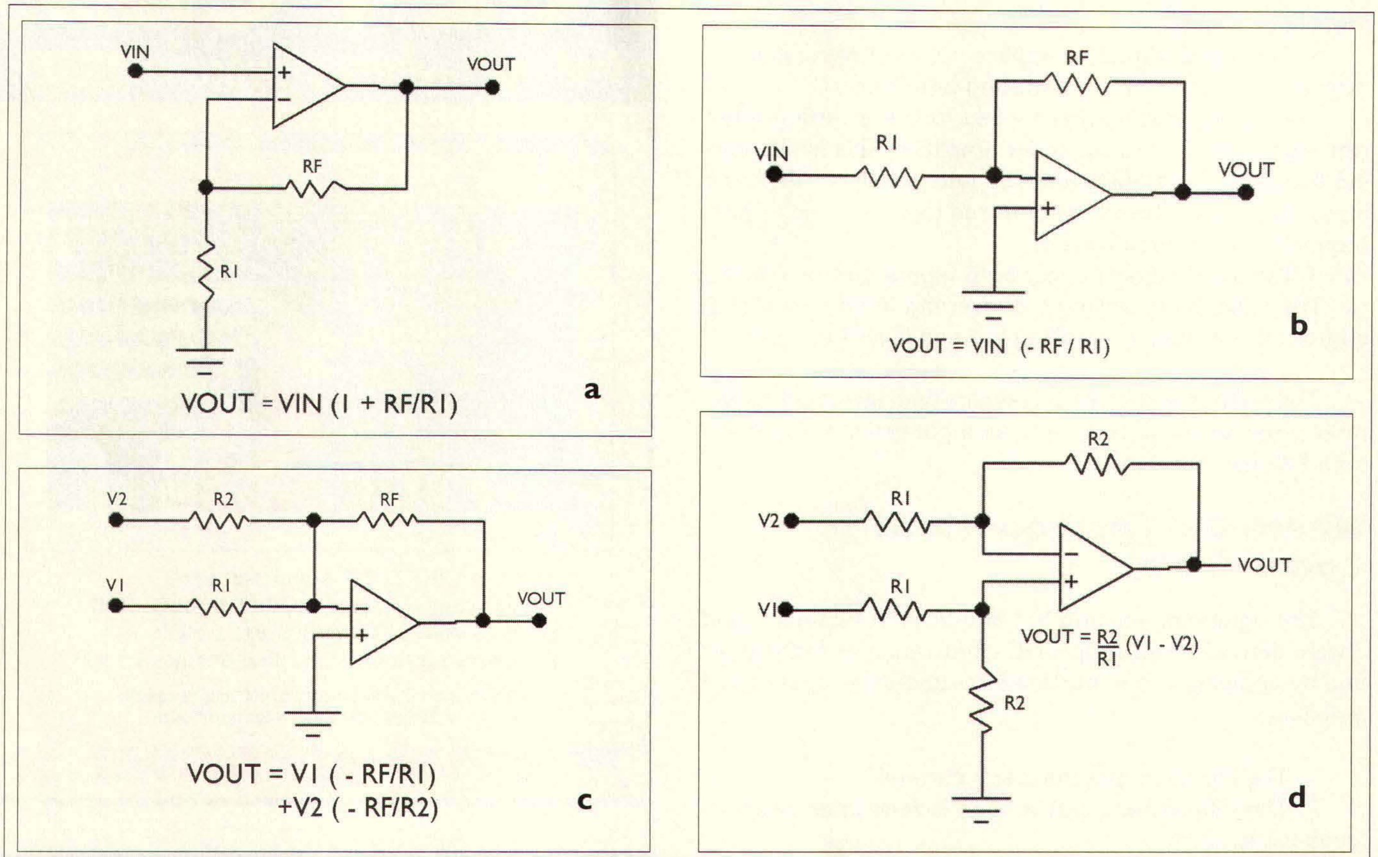


Figure 3: Basic operational amplifier configurations: a) Non-inverting amplifier; b) Inverting amplifier; (c) Adder (or Mixer) amplifier; and (d) Subtractor (or Difference) amplifier.

(10s or 100s of millions of ohms), that we can typically ignore the nano-ampere or pico-ampere current that may leak into the operational amplifier. So, we say the inputs do not draw any current, and that helps us apply Kirchhoff's current law during the analysis.

Second, when there is negative feedback, the operational amplifier will push or pull enough current (within reasonable conditions) through its output and feedback resistor to make the voltages at each input identical. This leads to a differential input voltage of zero. Another way of looking at this is to remember that the voltage on each input (inverting and non-inverting) must be identical when there is negative feedback.

So, let us see how the voltage gain of the non-inverting amplifier can be derived. Examine the circuit and analysis presented in Figure 4.

Step 1: The current through R1 will equal Vin divided by R1. Why does Vin appear across R1? Because the differential input voltage must be zero. The non-inverting input voltage is Vin, which means the voltage on the inverting input must be equal to Vin.

Step 2: Based on the direction of the currents chosen for analysis, together with Kirchhoff's voltage law, we have Vout equal to the sum of Vin and the voltage across the feedback resistor Rf.

Step 3: Because the inputs of the operational amplifier do not draw any current, Kirchhoff's current law allows us to say that the feedback current (If) equals I1.

Step 4: Substituting the equation for I1 into the Vout equation, we now have an equation containing only Vin and the circuit resistors on the input side.

Similar methods are used to derive the gain equations for the other configurations. Here are some hints in case you want to try the derivations yourself:

- **Inverting amplifier:** The current through R1 is the same as the current through Rf. The voltage at the inverting input of the operational amplifier is zero, what we call a virtual ground. Thinking about the differential input voltage should help you here.

James Antonakos is a Professor in the Departments of Electrical Engineering Technology and Telecommunications Technology at Broome Community College, with over 26 years of experience designing digital and analog circuitry and developing software. He is also the author of numerous textbooks on microprocessors, programming, and microcomputer systems. He can be reached at 615-513-9200.
antonakos_j@sunybroome.edu • www.sunybroome.edu/~antonakos_j

• **Adder:** Another virtual ground is present. The current in the feedback resistor is the sum of the individual input resistor currents.

• **Subtractor:** Label the voltage at each input of the operational amplifier Vx. Write two equations for Vx. One equation must use V1, R1, and R2. The other equation must use V2, R1, R2, and Vout.

Combining The Pieces

Figure 5 shows an operational amplifier circuit composed of each of the five basic configurations. I use this example with my students to help them recognize the basic configurations when they appear in a larger circuit. Let us work our way through the circuit, keeping track of voltages and equations as we go. Sample voltages have been assigned to assist with the analysis.

We begin with input Va (one volt), which is applied to the input of an inverting amplifier with a gain of -4. The output voltage is thus -4 volts. In general, the output voltage equals -4Va.

The -4 volt output is applied to one input of an adder. The gain associated with the -4 volt input is -2. This contributes eight volts to the output. The second input — Vb (two volts) — sees a gain of -5 and adds -10 volts to the output. The overall output voltage becomes -2 volts. In general, the output voltage equals 8Va - 5Vb.

The Vc (-1 volt) signal drives a non-inverting amplifier with a gain of five. The output voltage is thus -5 volts, or 5Vc in general. This voltage is applied to a voltage divider composed of a 4K resistor and a 6K resistor. The voltage across the 6K resistor is taken as the output voltage, which will equal 0.6 times the input voltage.

This gives an output voltage of -3 volts, or 3Vc in general. This voltage is buffered and applied to the lower input of a subtractor with a gain of five. The upper input of the subtractor is the adder output. The subtractor output voltage is five times the difference of -3 volts and -2 volts, or -5 volts. In general, the output voltage is 5(3Vc - [8Va - 5Vb]), or 5(-8Va +5Vb +3Vc).

A Little Thought-Provoking Silliness

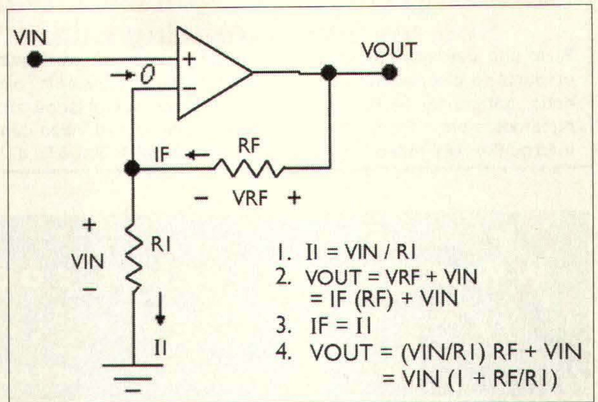


Figure 4: Deriving the voltage gain for the non-inverting amplifier.

After I have covered the circuit from Figure 5, I like to ask a few questions to see if the students can apply the rules of operational amplifier analysis to an actual circuit.

For example, how would the operation of the circuit change if there was no buffer amplifier between the non-inverting amplifier and the lower input of the mixer? Or, what are the largest voltages allowed on each input?

With no buffer following the 6K resistor, the resistors on the subtractor's non-inverting input will load the 6K resistor, changing the voltage divider ratio (it becomes smaller). This affects the contribution made by Vc to the output of the circuit.

The largest voltage possible on any input depends on the gain associated with the input and the voltage used to power the operational amplifier.

For example, if the device is powered with ±10 volts and the gain of the circuit is 50, the largest input voltage possible is 0.2 volts before the output will clip by hitting a power supply rail.

Conclusion

There are many other operational amplifier configurations, such as log amplifiers, absolute-value, integrator, and differentiator circuits, active filters, and oscillators. Every one of these circuits obey the same rules of analysis as the basic circuits presented here.

However, many of them require the use of complex numbers (real and imaginary numbers), so it is a good idea to brush up on your algebra before attempting an analysis. **NV**

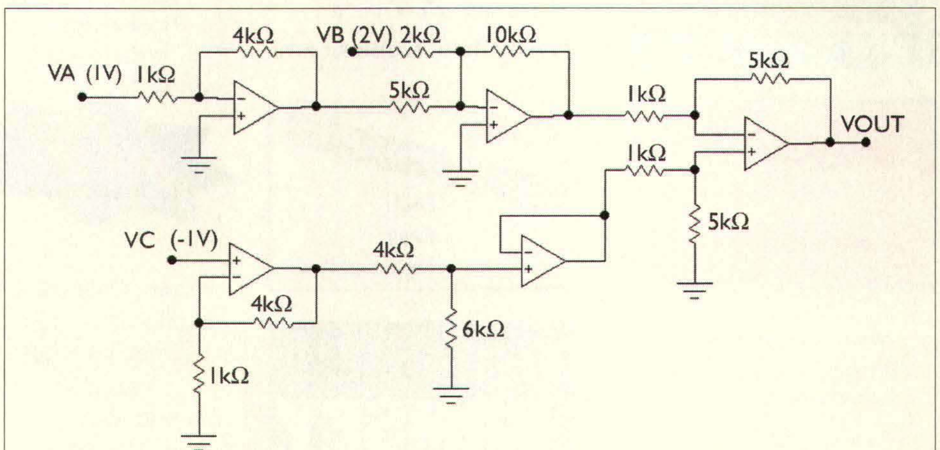


Figure 5: Combining the basic configurations.

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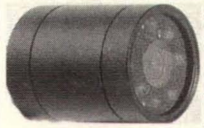

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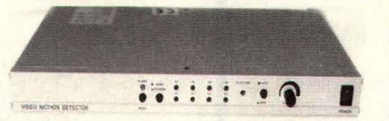

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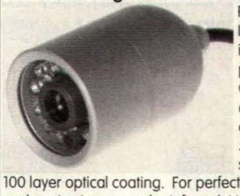

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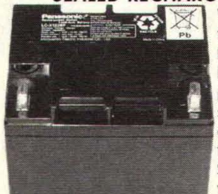

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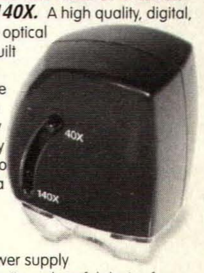

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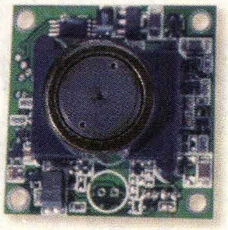

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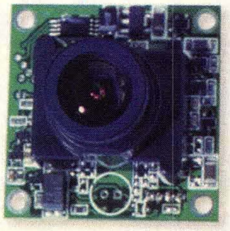

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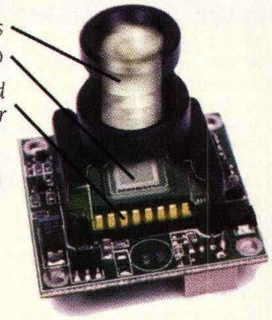

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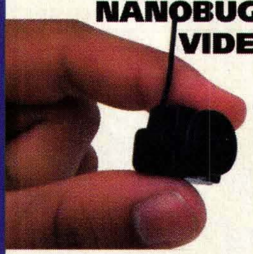

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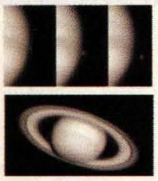

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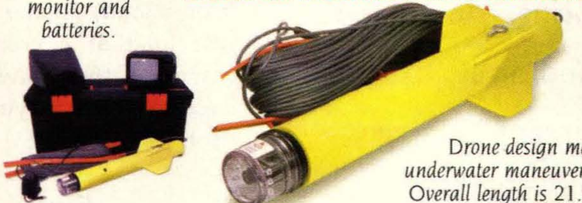

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Electronics Q&A

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:

Battery power, load, and monitoring. The LM386 explained, an IC fix, and a true current-limiting power supply. Finally, a Geiger Counter built around an NE2 neon lamp.

Electronic Loads

Q. I'm working with 36-volt battery chargers, and would like to test them out with some kind of variable load. I've tried old batteries, light bulbs, and resistors, but I want something more high-tech with variable control of the charging current, like maybe a transistor. It seems that power pass transistors should be capable of handling a load of 15 to 25 amps. Now throw in a potentiometer to vary that load, and that's what I have in mind. This design would also be useful for testing power supplies. Any suggestions?

R. Goff
via Internet

A. What you are describing is called an electronic load. There are two types: static and dynamic. In the static version, the load "resistance" is fixed, and the current is allowed to seek its own level according to Ohm's Law. A dynamic electronic load, on the other hand, sets the load at a constant current by varying the load resistance in response to varying load voltage. Both designs use a transistor for the resistance element.

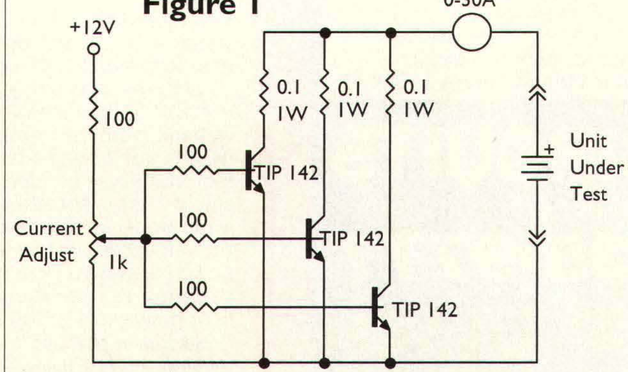
The static design, Figure 1, uses three bipolar transistors wired in parallel. The base of the transistors is driven by a current source that's controlled by the 1k potentiometer, which sets the load current as monitored by the 30-amp panel meter (catalog PMD-30A, All Electronics, **800-826-5432; www.allelectronics.com**).

Maximum current of this circuit is 25 amps.

The dynamic tester, Figure 2, uses a MOSFET operating as a constant-current source. The MOSFET is controlled by an LT1575 linear voltage regulator. In a typical voltage regulator design, a capacitor is hooked between the source of the transistor and ground. Using a feedback loop, the LT1575 maintains a constant voltage across the capacitor by turning the MOSFET on and off as needed. By replacing the capacitor with a fixed resistor (.08 ohms, in our case), the circuit becomes a current regulator.

Again, the LT1575 uses feedback to maintain a constant voltage across the resistor, which translates into a constant current. The current is controlled by an offset voltage which is supplied by the 78L05/LM336 combination. Calibrate the LM336 using the 10k pot for a value of 2.6 volts. The 1k pot now controls the load current: 0 volts is 30 amps and 2.4 volts is zero amps. You can monitor the current using a voltmeter

Figure 1



across the .08-ohm resistor using the formula I = 1.24E, or you can measure the current directly using the panel meter mentioned above.

Last, but certainly not least, the transistors MUST be very heavily heat-sinked. You see, the energy you are expending on the test is converted to heat — heat that would quickly melt the transistor(s) and anything around it.

Let's say you are testing 36 volts at 20 amps, that works out to be 720 watts of power — enough energy to run a toaster! (Lightly browned with butter, please.) Well, that heat has to be dissipated. As a rule, this requires forced air (or liquid cooling, in extreme cases). Before you start sending those cards and letters, I'm aware of the ratings of the transistors recommended, but they are rated using conventional convection cooling methods. Which means you need to use extra cooling measures — like forced air — or lower your current expectations.

Current Limitations

Q. Here is a schematic that shows how to increase the output current of an LM317 voltage regulator by adding a pass transistor. The circuit also adds (my addition) an adjustable current regulator, again using an LM317, to the voltage regulator. My question is: Can a pass transistor be added to the current regulator to increase its current handling capacity in the same way one was added to the voltage regulator section? Or is there a better way to increase both and, at the same time, keep it a simple circuit?

A. J. Anzevino
Wappingers Falls, NY

A. The circuit you sent is exactly as you described — a voltage regulator followed by a current regulator. Unfortunately, it won't do as you expect. The last stage is a current regulator, which means it will attempt to maintain the set current flow regardless of which voltage you set the LM317 at. For example, if you set the regulated voltage at five volts and the regulated current at one amp, one amp will flow through the load. Now if you increase the voltage regulator to 12 volts, the load will still see one amp, because the current regulator says so.

What you really want is a voltage regulator with adjustable current limiting. In this scenario, you maintain a constant voltage until the current reaches a threshold limit (that you set), after which the voltage drops off to prevent further current increase. Such a circuit is shown in Figure 3.

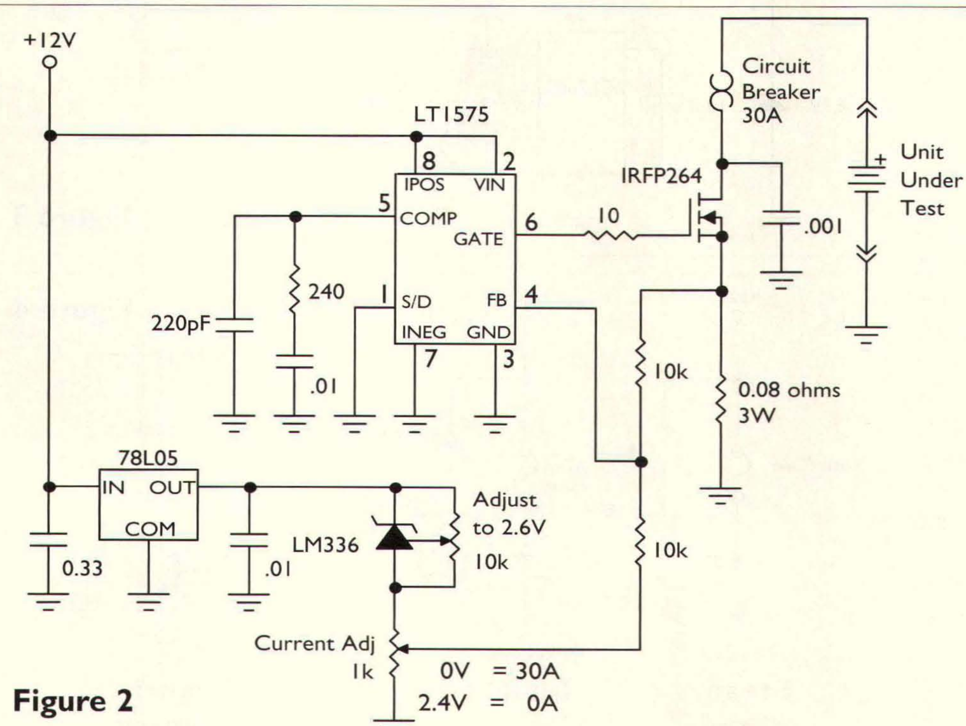


Figure 2

In this circuit, the Q1 pass transistor increases the output current from 1.5 amps to 5 amps, as your design did. But that's the only thing that remains the same. Unlike your design, the current is allowed to follow the voltage, which is set by the Voltage Adjust pot — up to a point. That point is set by the Current Adjust pot. If the output current exceeds your current limit, the voltage drops accordingly. This is unlike a fuse or circuit breaker, which disconnects the load. The voltage simply tapers to zero volts as the constant-current function kicks in. As the load lightens, the voltage will proportionally return.

The difference between your approach and this one is the inclusion of an op-amp. The op-amp is operated in an open-loop feedback path. As long as the voltage across the 0.2-ohm current sensing resistor remains below the level set by the Current Adjust pot, the op-amp is out of the loop. But let that voltage exceed your preset level, and the op-amp starts to adjust the output voltage of the LM317 by forcing its COM pin to ground. When this happens, the LED will light, indicating an over-current condition. Sorry, but this is as simple as I can make it. I'm open to other solutions from our readers.

Fuse Monitor

Q. It is my understanding that transistors are like NO relays in that a small current on one side will allow a large current on the other. Are there any transistors that can act as an NC relay so that the absence of current will allow a current on the other? I want a transistor and LED to let me know when I blow a fuse in my car (the lack of voltage after the fuse will indicate a blown fuse and will light the LED).

Adam Huber
via Internet

A. If all you want is to indicate a blown fuse in your car using an LED, I have something simpler, shown in Figure 4 under the headings of Steady Glow and Blinking. Okay, let's say your heart is set on using a transistor solution (because you want a single sense line), then use the configuration on the right (Transistor Version).

Repair An IC? Sometimes, Yes.

Q. I have a number of systems that uses a UN 101 integrated circuit, with the following pinout (Figuer 5). Unfortunately, several of them are defective, and finding replacement parts is next to impossible. In all cases, the failure is that pins 13, 14, and 15 are shorted. What I'd like to do is cut off these pins and replace them with an appropriate discrete device. Is this possible?

Mr. Resistor
Fort Lauderdale, FL

A. In all cases? Sounds like a design failure, like perhaps the part was stressed beyond its limits — or you happened to be unlucky enough to acquire a batch of bad chips. Whichever, you are in luck in

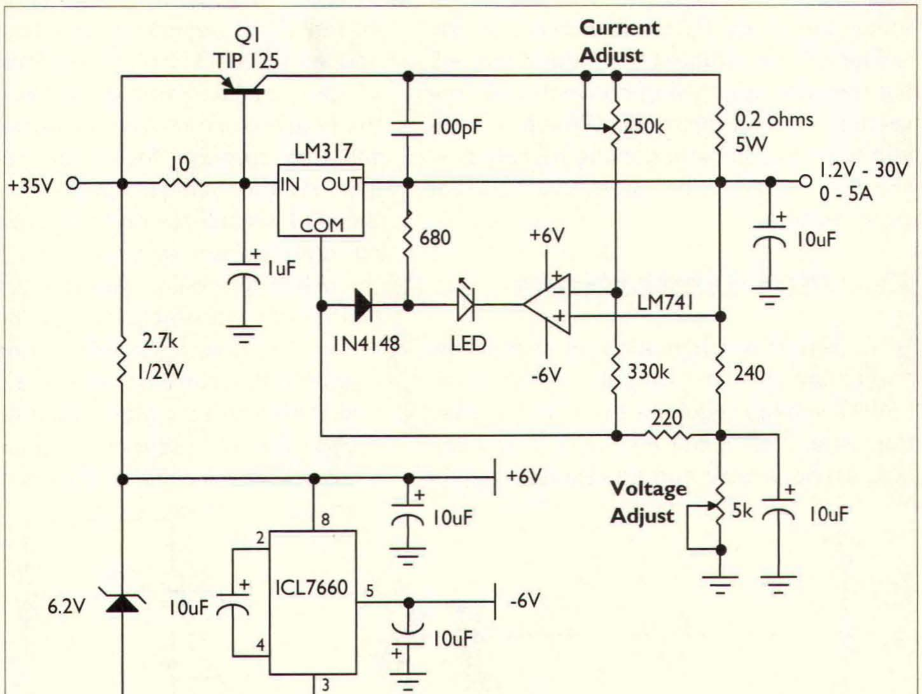


Figure 3

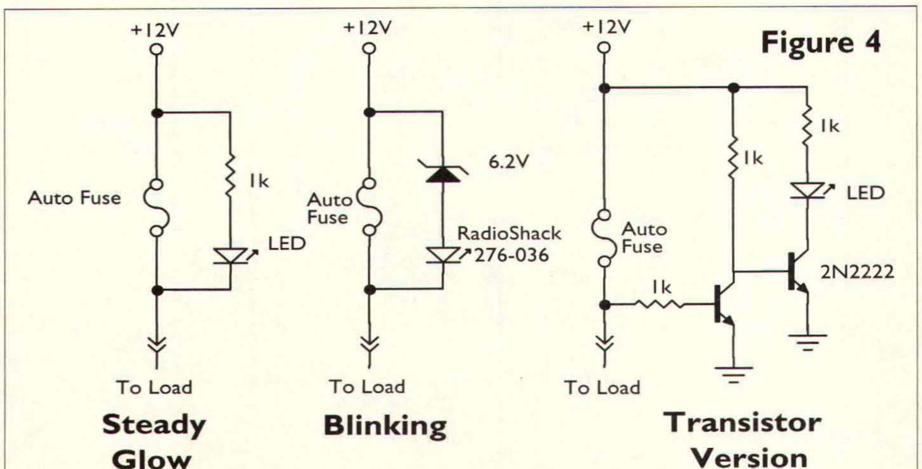


Figure 4

Figure 5

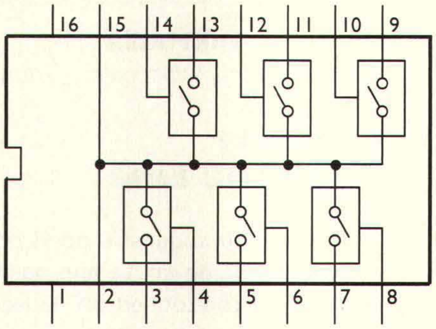
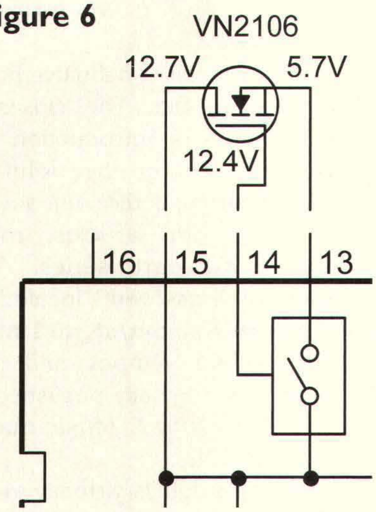


Figure 6



that you can replace the defective section with a VN2106 MOSFET. Here is the fix (Figure 6), with your voltages included.

I was able to do this because you sent enough of the schematic for me to decipher the part's function. Basically, the UN 101 is a hex bilateral analog switch identical in operation and performance to the 4066 quad bilateral analog switch — effectively a solid-state SPST relay. In your application, these "relays" are used to switch a 12-volt source to selected circuits, something a MOSFET transistor does quite well. For it to work, though, the gate voltage must be at least 2.5 volts higher than the source voltage.

BTW, while researching this answer I happened to run across an interesting device from Texas Instruments: A single bilateral analog switch with a switching speed of 200 MHz (the 4066 has a switching speed of 6 MHz) that's suitable for use in high-frequency designs.

LM386 Unveiled

Q. I just received the Dec. 2002 issue, and on page 25 there's a diagram for an Audio Power Oscillator I'd like to build. But I don't know if I should connect the LM386's gain pin with the bypass pin. In fact, I've seen other LM386 designs where sometimes the pins are connected and other times not connected. I'm getting confused about connecting the LM386. Can you please describe LM386 pin-for-pin connections within this diagram?

Marcel
via Internet

A. I'll do you one better. I'll describe in detail each pin of the LM386. Normally I wouldn't do this, but I use this chip so often — as do many others — that it merits looking at. I'd keep a clip of this answer and tape it to my workshop wall so that the next time a question arises, the answer will be in front of you. First, the overview. (Figure 7)

The LM386 is a power amplifier designed for use in low-voltage applications. The gain is internally set to 20. That is, with no other pins involved, you have a very simple 20x audio power amplifier with about a 1/2W output. This involves just the pins of 2, 3, and 5 (of course, you need

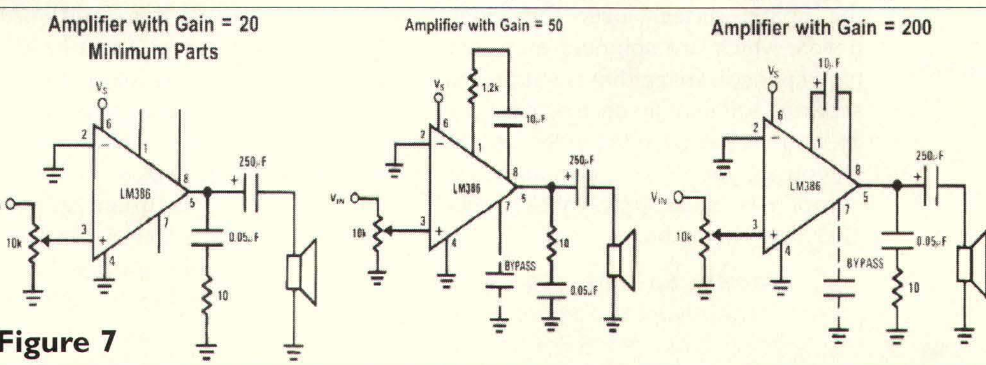


Figure 7

Congratulations to our December Prize Winners:

Richard Brohmer
Warsaw, MN

Jerry Kienitz
Camarillo, CA

pins 4 and 6 to power the chip). That all by itself makes it a staple in any experimenter's junk box. Those extra pins you ask about? Well, that's what makes the LM386 special.

Let's talk about the gain first. Buried deep inside the LM386 is a 1.35k feedback resistor that's connected between pins 1 and 8. Refer to Fig. LM386.TK. If a capacitor is placed across pins 1 and 8, it shunts the 1.35k resistor and increases the gain from 20 to 200. If you place a resistor in series with that capacitor, the gain falls somewhere between 20 and 200, depending on the value of the resistor. Typically, a series resistor of 1.2k will result in a gain of 50.

Additional components can be placed between pins 1 and 5 (output) to tailor the gain and frequency response for individual applications. For example, you can boost speaker bass response by shaping the feedback path using resistors and capacitors.

Speaking of the output pin, you should hang a 10-ohm/.05uF, resistor/capacitor combination from the output (pin 5) to ground to prevent parasitic oscillation. While it's not required, it's generally considered good engineering practice. As for pin 7, it too is available only to squelch parasitic oscillations. In other words, if you have an unstable circuit, placing a .01 uF capacitor between pin 7 and ground may tame it — no guarantee.

Cool Web Sites!

The Nanotube Site: A page of links to nanotube information, research efforts, events, jobs in nanotube technology, and more.

www.pa.msu.edu/cmp/csc/nanotube.html

Ever wondered what all those different Ethernet flavors mean? Webopedia's quick reference chart helps you sort them all out. Find out here.

www.webopedia.com/quick_ref/EthernetDesignations.asp

My VCR Ate My Homework, Really!

Q. My VCR "ate" my son's most prized tape. The crinkle is at the beginning, just after the clear leader. I'm sure I can repair it by cutting off the damaged tape and re-attaching it to the leader. However, a search of the Internet for a supplier of video splices found nothing but people who are willing to do it for a fee, but no supply companies. Can you help?

John Fitzgerald
via Internet

A. In your case, yes. In fact, in most cases the answer is yes to repairing a broken VCR or Beta tape. If the plastic cassette was broken from being dropped, the tape can be transferred into a new housing. If the tape itself was damaged or broken, the tape can usually be saved using a splice, or patch.

However, there are mixed opinions about tape splicing. One camp says that putting a patch over the tape ends to mend the break is okay and permanent. Others, however, contend that unless the splice is located at the very beginning or end of a tape where it attaches to the clear leader, the patch is just a "Band-Aid" fix. If the splice is anywhere in the middle of the tape, the fix should be considered strictly temporary and the tape should be immediately duplicated. The reasoning here is that the splice is made with an adhesive splicing tape and adhesives, by nature, will fail in one way or another over time and use. When the splice passes over the video heads, which are spinning at a very high speed, a splice that is starting to separate will usually destroy the fragile, and very expensive, video heads. Of course, you need to decide. As for companies that supply splicing supplies, here are a few.

Family Safe Media
www.familysafemedia.com/home_movie_editor.html

TAC
www.bgsales.com/video/splice.asp

TekMedia
www.rtico.com/tekmedia/1_3.html

Crossing Over The Line

Q. Can you suggest a good book for designing active and passive crossovers? I've looked on Amazon, but the reviews for each are mixed.

Al Lovecky
via Internet

A. I couldn't find a definitive book on the subject. The closest I could come was Introduction To Loudspeaker Design by John L. Murphy. However, I did run across some very good articles, most notably a two-part series, "An Overview of Crossovers" located at **www.trueaudio.com/st_mr1.htm**, written by John Murphy and Jim Ford that was originally published in *Modern Recording & Music* magazine, August 1980.

The article details virtually every aspect of designing and implementing passive crossovers. Although the article is targeted at the audiophile, specifically for speaker design, the information is applicable to most electronic designs.

Located on the LaLena web site **(www.lalena.com/audio/faq/xover/)** is a detailed discussion and example of how to design a three-way crossover system. The site also includes a free crossover calculator that does the math for you for a wide range of filter types, ranging from first order Butterworth to fourth order Bessel to sixth order Linkwitz-Riley, and everything in between. Another good web site with a similar free calculator is at **www.the12volt.com/caraudio/cross.asp**.

An excellent treatment on active filters can be found in Don Lancaster's book *Active Filter Cookbook*, which is in its sixth printing and is available from Amazon.com, or *Simplified Design* *of Filter Circuits* available from the *Nuts & Volts* On-Line Store (**www.nutsvolts.com**).

Keeping Up With The Times

Q. Regarding the Oct. 2002 column about the Solar Powered regulator, you used an LF355 op-amp. I located one of these at Digi-Key, but it is listed as obsolete. Is it possible to substitute an LM741 (or some other more current IC) for this circuit, or is there some obscure reason that the LF355 JFET is more desirable. Also I assume that a 1N4735 zener can be substituted for the 1N753 since both are rated at 6.2 volts. When you get a chance, I would appreciate your comments.

Jack Mickelson
via Internet

A. No, use an LF356 instead; it has basically replaced the LM355. Another replacement for the LF355 is one-half an LF353. Essentially, this design requires a high-impedance input with little drift. In my defense, let me say that 500 semiconductors become obsolete everyday, and a matching number are announced as new products. It's kinda like keeping up with a kid on a fast skateboard. I do my best, but often my hands are tied because most hobbyists prefer DIP footprints over the newer SO-types. Hence, I specify older parts still in production (and I do check for availability). You'll notice, though, that I'm using more and more SO-23 footprints and their cousins in my answers. That's the trend, and I would be delinquent in my duties not to address it.

I'm not sure about the zener diode substitute. The 1N753 is rated at 20mA and the 1N4735 is rated at 41mA. One of the reasons I picked a 6.2-volt zener is that they are extremely stable when operated in their range. Replacing a 0.5W zener with a 1W zener may make the design more temperature-sensitive given the current I specified.

MAILBAG

Dear TJ:

It's good to see CP/M mentioned. Just for the record, please note that CP/M was written by Gary Kildall (AKA, Digital Research) for the Intel 8080, not the Zilog Z80. It would run on a Z80, of course. I rewrote both the kernel and the shell of CP/M 2.2 and my version, called RP/M, also ran on either an 8080 or a Z80. My brother Jim wrote a Z80 emulation package for the IBM PC and we ported RP/M to the PC using his Z80 emulator. By the time we got to market, though, DOS had pretty well taken over and so it all kind of faded away.

If Orio Hudson is interested, I could send him a 360K IBM floppy that will boot ZR/PM on a PC. It includes most of the utilities that a CP/M user expects to find. Anyhow, them was the days!

Jack Dennon
jdennon@seasurf.com

Dear TJ:

I finally downloaded Musicmatch and thought we were ready to put our old LPs on CD. MusicMatch is a great program, but the free download version does not give you the ability to record from outside sources. You have to buy the Plus version. However, at $20.00, it is a bargain. My brother-in-law has it and he is very happy with it. My wife and I will be ordering it today. You might want to mention the Plus version as a P.S. to the November column.

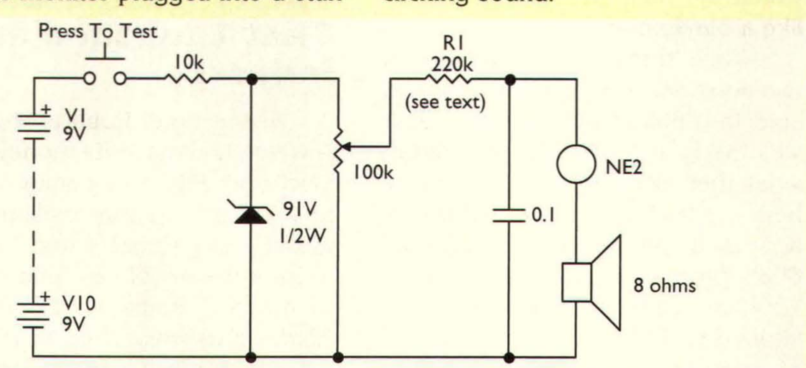
Tom Grabowski
via Internet

Editor's Choice

In these trying times of increased world tension, the possibility of a nuclear incident is more than a passing concern for many. So much so that about a year ago I answered a reader's letter describing a cheap Geiger Counter using a $30.00 Miller tube. So I was really delighted when I ran across this "Ideas for Design" in a recent issue of *Electronics Design* magazine, which replaces the Miller tube with a cheap neon glow lamp. [The contributor passed along the idea from his German-written book about experiments with radiation sources, Experimente mit Strahlenquellen in Haushalt (**www.peterlay.de**).]

Unfortunately, the original design had the monitor plugged into a standard wall outlet. As with all circuits that connect directly to the AC line, there is the risk of electric shock. I've modified this circuit slightly to make it safer and more portable by converting it to battery power.

The power source is simply 10, nine-volt batteries wired in series, and stabilized by a zener diode (NTE 5049A, or equivalent). Set the potentiometer so that the voltage across the lamp is at the ignition threshold — that is, just below the point where the lamp lights. When a radioactive particle passes through the lamp, the gas ionizes and current flows. The value of R1 is selected so that it won't sustain conductance, so the lamp returns to its inactive state. Each time the lamp fires, current also flows through the speaker and produces a clicking sound.



by Ed Driscoll, Jr.

Micro Memories

The Spark That Ignited a Revolution: The Altair 8800

I'll never forget the day I saw my first personal computer. I was about 10 years old, attending a small New Jersey school, when I walked into the classroom where it was kept. It was an Altair 8800, which my school had acquired in 1976. Seeing that machine for the first time, it was a bit like all of my dreams from watching Star Trek and Hal from 2001: A Space Odyssey had come true.

The Altair — as it was initially sold — was little more than an incredibly difficult to assemble computer kit — basically a computer case with some circuit boards and a processor. It also initially had next to nothing in the way of peripherals. Unlike today's PCs, not even a keyboard was bundled with it. And a mouse? Fogetaboutit, as they say back in New Jersey. So my school's Altair was hooked up to a converted Western Union teletypewriter, which was being used as its keyboard and print-out device. The monitor — a converted television set — would come a little later. Programs were entered in and saved to paper tape, which the machine punched, a bit like a player piano.

While there had been one or two personal computer kits that had sold in small quantities, the Altair was the first to be manufactured in what then seemed like large numbers — about 10,000 were ultimately sold. It was powered by an Intel 8080 processor, and shipped with 256 bytes of RAM (that's bytes, not kilobytes). But we're getting ahead of ourselves. By early 1974, Ed Roberts was an Albuquerque, NM businessman with a venture he dubbed Micro Instrumentation and Telemetry Systems, or MITS for short. It was hardly the roll-off-your-tongue business name that would later distinguish such personal computer heavyweights as Apple, Commodore, and Dell, and in the classic marketing book, *Positioning* by Al Ries and Jack Trout, the authors argued that the combination of both poor business and product names contributed to the eventual death for the Altair — once a company whose products had a friendlier (not to mention catchier) name came along. (In other words: Apple.)

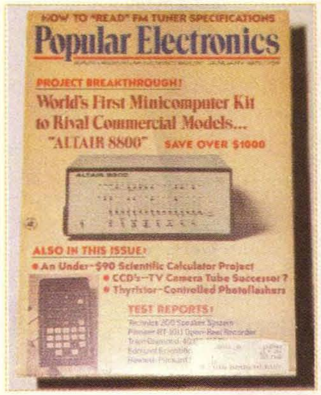
The Magazine Cover That Launched an Industry

At the time, Roberts' company — which had made its money selling electronic kits and pocket calculators — was a quarter million dollars in debt. But Roberts was fortunate to have the ear of Les Soloman, the technical editor of *Popular Electronics* magazine. At the time, using a computer meant timesharing a mainframe, and Soloman knew there was intense interest among electronic hobbyists in building a small personal computer, one that could be used anytime, rather than waiting in line. By 1974, Soloman was receiving a regular supply of plans, diagrams, and articles on the subject of how to build a personal computer, but he worried that most of the plans weren't up to snuff. He contacted Roberts, whom he had known from previous articles he had submitted. Roberts suggested designing a computer around the then — brand-new Intel 8080 chip. That chip was the key to the Altair — and also a big part of its hype. Intel normally sold its chip for $360.00 each, a price that they created to spoof IBM's 360 mainframes, which sold for millions of dollars each. But Roberts was able to keep the final retail price of his Altair kit at only slightly more than the 8080 chip itself, by buying cosmetically-damaged "seconds" in quantity from Intel at $75.00 a chip.

The Trek Connection

The famous story of how the Altair got its name is that Roberts asked his young daughter for some suggestions, and she came up with the idea of naming it after a planet the USS Enterprise was visiting on Star Trek that week — Altair. (At the risk of outing myself as a proto-Trekkie, this was probably the "Amok Time" episode, where Kirk and crew were scheduled to visit

Altair, but end up at Spock's home planet, Vulcan.) The Altair name has some additional science fiction resonance — it was also the planet where Leslie Nielson and crew met Robby the Robot in Forbidden Planet. Robbie's capabilities would run rings around the Altair 8800, but they'd probably still find some common kinship.



Enter Bill Gates and Paul Allen

Roberts had hoped his Altair kit would sell a couple of hundred units, while he looked for other, more lucrative projects. Little did he know that he'd be taking 200 phone orders a day for the computers, or that people would actually drive out to Albuquerque and camp out overnight waiting to pick up their kits. (Roberts sold 1,500 Altairs in its first year of sales.) Or that he'd be launching his eventual successor as king of the personal computer world: Microsoft.

Roberts was painfully aware that his computer lacked the software necessary to do anything useful. Fortunately, help arrived in the mail, in the form of a letter from two equally experienced veterans of 1970s computing: Bill Gates and Paul Allen (Yes, that Bill Gates and Paul Allen). At the time of the Altair's announcement in *Popular Electronics*, Paul Allen was a programmer employed by Honeywell, where Gates had worked during summers, and Bill Gates was a sophomore at Harvard. In an eerie foreshadowing of how the IBM PC came to have a Microsoft operating system, Gates and Allen were in the right place at the right time: the Altair desperately needed a pre-written operating system to make it more than just a plug-in doorstop, and Gates and Allen got there first by modifying an existing operating system. The BASIC language was originally created in 1964 at Dartmouth, and was used on numerous mainframes as an easy-to-learn computer language, perfect for beginners. Gates and Allen worked in marathon 24-hour sessions to adopt the language to the peculiarities of the Altair, and then licensed the result to MITS.

Soon thereafter, Allen accepted a position with MITS as director of Software Development, where he stayed until the end of 1976, when he and Gates resumed their nascent Micro-Soft business, complete with hyphen.

The Altair Begets a Clone

Just as the first IBM PC would eventually begat numerous clones, the Altair had a clone of its own: the Imsai 8080. Many users of both computers actually consider the Imsai to be a much better design, given its higher specification power supply, an anodized aluminum chassis, and a more functional front panel design. All for the same $439.00 as a kit, or $621.00 assembled price of the Altair, only slightly more than what the Altair initially cost. Upgraders could insert Imsai cards into an Altair, and via Imsai's "Memory Sharing Facility," an Altair and Imsai processor could co-exist in the same platform for parallel computing. The Altair's sales eventually topped 10,000.

While Altairs served on the front lines of personal computer usage for the rest of the 1970s, their time was gradually numbered. Roberts sold the MITS name to Pertec, a manufacturer of tapes and disk drives for mainframes. By then, the Apple II, the TRS-80, and other personal computers had entered the market and began to cut drastically into the Altair's sales. Pertec eliminated the model within a couple of years of their acquisition. But the Altair had served its initial role well: the personal computer revolution was set to go, and just needed a spark. **NV**

Dealer Directory

STORE CHAINS
Barnes & Noble
Books-a-Million
Borders Books
Frys Electronics
Hastings
Tower Books, Records & Video
Universal News

ALABAMA
Little Professor Book Center
2717 S. 18th St.
Birmingham 35209

ARIZONA
Elliott Electronic Supply
1251 S. Tyndall Ave.
Tucson 85713

AUSTRALIA
DonTronics
P.O. Box 595
29 Ellesmere Cres.
Tullamarine 3043
www.dontronics.com

CALIFORNIA
Abletronics
9155 Archibald Ave. Unit E
Cucamonga 91730

All Electronics
905 S. Vermont Ave.
Los Angeles 90006
14928 Oxnard St.
Van Nuys 91411

Builders Booksource
900 N. Point Ghirardelli Square
San Francisco 94109
Centerfold International
716 N. Fairfax Ave.
Los Angeles 90046
Copperfield's Books
140 Kentucky St.
Petaluma 94952
Electro Mavin
2985 E. Harcourt St.
Rancho Dominguez 90221
Green Apple Books
506 Clement St.
San Francisco 94118

HSC Electronic Supply
4837 Amber Ln.
Sacramento 95841
3500 Ryder St.
Santa Clara 95051
5681 Redwood Dr.
Rohnert Park 94928

JK Electronics
6395 Westminster Ave.
Westminster 92683
Lion Electronic Labs
4948 E. Townsend Ave.
Fresno 93727
Kepler's
1010 El Camino Real
Menlo Park 94025

Mar Vac Electronics
2001 Harbor Blvd.
Costa Mesa 92627
12453 Washington Blvd.
Los Angeles 90066
4747 Holt Blvd.
Montclair 91763
2000 Outlet Center Dr.
Ste. 150
Oxnard 93030
1759 Colorado Blvd.
Pasadena 91106
5184 Hollister Blvd.
Santa Barbara 93111

OPAMP Technical Books
1033 N. Sycamore Ave
Los Angeles 90038
Sawyers News, Inc.
733 4th St.
Santa Rosa 95404
Sav-On Electronics
13225 Harbor Blvd.
Garden Grove 92643
Video Electronics
3829 University Ave.
San Diego 92105

CANADA
Emma Marion Ltd.
2677 E. Hastings St.
Vancouver, BC V5K 1Z5
Muir Communications Ltd.
3214 Douglas St.
Victoria, BC V8Z 3K6

COLORADO
Centennial Electronics, Inc.
2324 E. Bijou
Colorado Springs 80909

CONNECTICUT
Archway News
64 Bank St.
New Milford 06776

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Astro Too
6949 W. Nasa Blvd.
West Melbourne 32904
Clarks Out of Town News
303 S. Andrews Ave.
Fort Lauderdale 33301
Mike's Electronic Distributing Co.
1001 N.W. 52nd St.
Fort Lauderdale 33309

HAWAII
SolarWorks!
525 Lotus Blossom Ln.
Ocean View 96737

IDAHO
Boise Food Co-op
888 W. Fort St.
Boise 83702
Current Source
454 N. Phillippi St.
Boise 83706

INDIANA
Surplus Bargain Center
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Indianapolis 46222

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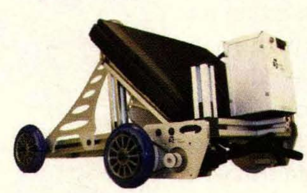

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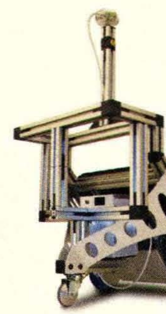

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by Gordon McComb

"Where It Is and How to Get It"

Robotics Resources

$200.00-and-up Robot Kits

Last month, we looked at a gaggle of under-$200.00 ready-to-go robot kits. These kits provide all the necessary components to build a basic robot, in some cases, including a microcontroller or other electronics. Just assemble, and you're off.

The under-$200.00 kits provide a great deal of flexibility and power. But if you're looking for something a little more advanced, a few dollars more will buy you sophisticated two-, four-, and six-legged walking robots, heavy-duty robot platforms, enhanced sensory abilities, and more. The field of $200.00+ robots is a large one, with far too many products to cover in one sitting. So for this month, we'll discuss 10 major producers of high-end robot kits, and catch the others in future columns. Ready ... set ... we're off!

Parallax

www.parallaxinc.com/

You know Parallax as the makers of the ever-popular BASIC Stamp family of microcontrollers. But they also manufacture several worthy robot kits. First in line is the BOE Bot ($219.00) — BOE stands for Board of Education (no, not Bored of Education, thank you). The kit comes with everything you need to begin your robotics hobby: metal robot chassis, two pre-modified R/C servo motors, wheels, BOE experimenter's board, BASIC Stamp, software CD, AC adapter, and PC interface cables. A slick robotics how-to book comes with the kit, and it provides full construction plans, theory of operation, initial set-up, and beginner's experiments.

The BOE Bot is resold by numerous Parallax dealers. Rather than list them all (and probably miss some), just check out the Parallax web site, as noted above and click on the Distributors link.

A similar product is the GrowBot ($219.00). It's like the BOE Bot, but designed with a different experimenter's board. It doesn't offer the solderless breadboard area, and it requires more assembly time.

A relatively new addition to the Parallax product line is the Toddler ($299.00), an intriguing two-legged walking robot. The Toddler uses a pair of unmodified R/C servo motors to propel the robot forward and in turns. The structural components of the kit are machined from anodized aluminum; you have your choice of gold or blue. A BASIC Stamp 2 and experimenter's board come with the kit.

Figure 1

The Parallax Toddler is a two-legged walking robot made from machined aluminum pieces.

Lynxmotion

www.lynxmotion.com/

No one has a wider variety of robot kits than Lynxmotion. Products include stationary arms and grippers, two- and four-wheeled rolling robots, and four- and six-legged walking robots. Much of the

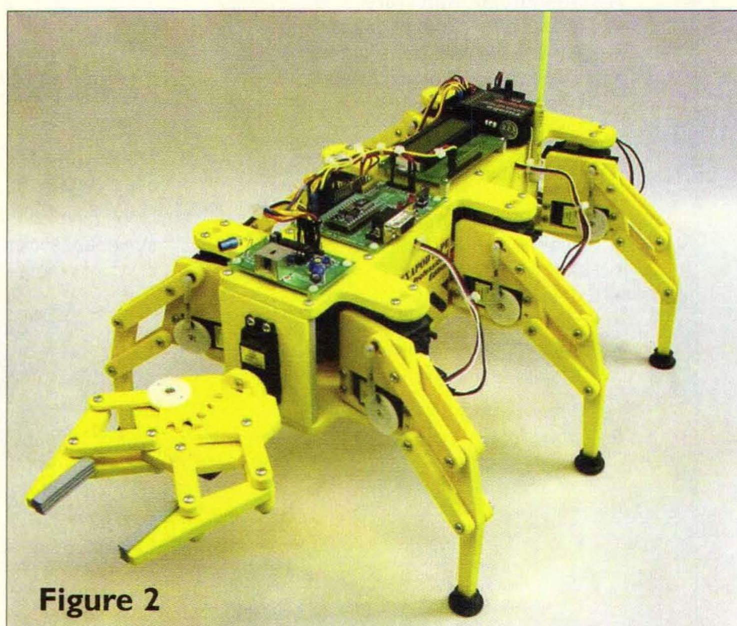

Figure 2

Among Lynxmotion's yellow robot kits is the Hexapod 2, which sports 2 DOF movement per leg.

product is laser-cut acrylic plastic, and many kits are available with just the plastic parts, hardware, and motors (typically R/C servo motors, modified and unmodified). You can add your own control electronics, or opt for Lynxmotion's FirstStep or NextStep controller carrier boards. Both are designed to be used with the BASIC Stamp microcontroller (included with the FirstStep, extra on the NextStep).

Perhaps the best known (at least most seen) of Lynxmotion's distinctive yellow robots is their Hexapod walker. They offer several variations:

- The Hexapod I combo kit ($232.00) comes with all parts (but not a controller) to construct a three-motor, six-legged walking robot. Two of the servos control the front and back legs on either side, and the third servo controls the middle legs.
- The Hexapod 2 (parts/motor kit: $375.00; full kit $685.00) uses 12 servos; two per leg (for two degrees of freedom, or 2 DOF, per leg). Each leg is individually-controllable, so this robot is capable of performing numerous styles of walking gaits.
- For 3 DOF, Lynxmotion offers the Hexapod 3 ($682.00), which comes with 20 servos, 18 of which are used for locomotion.
- The Quadrapod 2 ($569.00) and Quadrapod 2S ($404.00, no electronics) are four-legged walkers. Both provide 2 DOF per leg.

Other Lynxmotion kits include several variations of wheeled Carpet Rover robots, a number of Japanese-class Sumo kits, and the Mobile Arm Kit ($250.00).

Living Machines/Diversified Electronics

www.robotalive.com/

Diversified Electronics — now Living Machines — makes and sells the popular Descartes (pronounced day-kart) autonomous robot. This $229.00 kit measures six inches in diameter, and uses its main circuit board as the chassis. A pair of small motors and wheels are attached to the circuit board and provide motive power; the board also houses four CdS light cells, left and right mechanical bumper switches, speaker, and two wheel encoders (for distance-of-travel odometry).

Descartes uses the BASIC Stamp 2 as the main microcontroller, which can be programmed with your own code, plus a non-reprogrammable PIC microcontroller for numerous co-processor functions.

Also available from Living Machines is the Pocket Bot ($379.00), a miniature robot small enough to fit in the palm of your hand, and a 12-inch diameter PVC plastic general-purpose base ($350.00), which comes with modified R/C servo motors, rubber tires, dual motor encoders, and twin support casters.

Mekatronix

www.metkatronix.com/

Mekatronix manufactures a small line of wheeled and legged robots. Sales are through distributors; for the United States, the Mekatronix product line is available through Mr. Robot **(www.mrrobot.com/)**. Most of the kits are available pre-cut in either five-ply aircraft plywood, or black ABS plastic. In most cases, you can buy the body only, or full kits with all parts and electronics. The prices below are for the full kits.

Leading the pack is the Talrik line of small wheeled autonomous robots. All use modified R/C servo motors. Talrik Jr. ($239.00) is seven inches in diameter, and is the entry-level kit of the group. There's also Talrik Jr. Pro ($339.00), and Talrik II ($639.00), at 10 inches in diameter.

The company's Robobug is a hexapod walker with 2 DOF per leg. Price for the full kit — wood parts, 12 servos, and hardware — is $499.00. A microcontroller is extra.

Arrick Robotics

www.robotics.com/

The ARobot from Arrick Robotics is an all-purpose metal robotic platform. Unlike most wheeled robots that use a pair of drive motors, the ARobot uses just one drive motor, along with a separate R/C servo motor for steering. The drive motor propels a single wheel in the front, and the steering motor controls a pair of rotatable wheels in the rear. These two wheels are linked to the one steering motor by a push rod.

Included with the $235.00 ARobot kit is a pre-cut aluminum base, motors, wheels, and other parts, controller board, but no microcontroller brain. The controller board is designed for use with the BASIC Stamp 2, which means you can use the Stamp or a pin-compatible alternative, such as the BasicX-24, Basic Micro Atom, or OOPic C.

Another unique aspect of the ARobot is its included wheel odometer, which allows it to track distances traveled.

AK Peters

www.akpeters.com/

Known mainly as a book publisher, AK Peters is also a distributor of the Rug Warrior line of educational robots. The Rug Warrior is described in *Mobile Robots: Inspiration to Implementation*, which the company publishes. The Rug Warrior kits are not cheap, but are well thought out, and are common finds in college- and university-level mechatronics labs.

The Rug Warrior Pro ($599.00) provides a complete kit of parts to build a fully-functional autonomous robot based on the Motorola MC68HC11 microcontroller. Included is the chassis, wheels, motors, main electronics board with microcontroller and other support components (including a two-line LCD display and dual H-bridge motor driver), dual shaft encoders, light sensors, and speaker.

The Rug Warrior kit comes with Interactive C, a special multitasking version of C designed for the Motorola controllers, and is used heavily at the MIT robotics lab.

Rug Warrior is available in various "sub" kits, should you already have the mechanical base or electronics. The Brains kit (microcontroller and support electronics) retails for $359.00; the Brawn kit (chassis, motors, wheels, etc.) retails for $240.00. Unlike AK Peters' books, the Rug Warrior kits are not available at bookstores; rather, they can be purchased from online distributors, such as Acroname **(www.acroname.com/)**.

Robodyssey Systems

www.robodyssey.com

The robot kits from Robodyssey are aimed squarely at the educational market. The company's Mouse ($206.00) uses twin modified R/C servo motors, mounted on a small circular aluminum chassis. The Roach ($259.00) is a six-legged walking robot using three unmodified servos for a "linked" walking gait.

Both kits are provided with a central control board, but not a microcontroller. The control board is designed for use with the BASIC Stamp 2 or pin-compatible microcontroller, such as the BasicX-24. A nice feature of this control board is its 24-pin zero-insertion force (ZIF) socket. This allows you to more easily remove and install the microcontroller without damaging the pins, or unnecessarily expanding the spring contacts in the socket.

Zagros Robotics

www.zagrosrobotics.com/

Zagros is a manufacturer of "rover size" robot bases and kits. Almost all of the kits discussed so far are desktop robots, and small enough to fit on one. The fare from Zagros is designed for DIY educational and industrial applications,

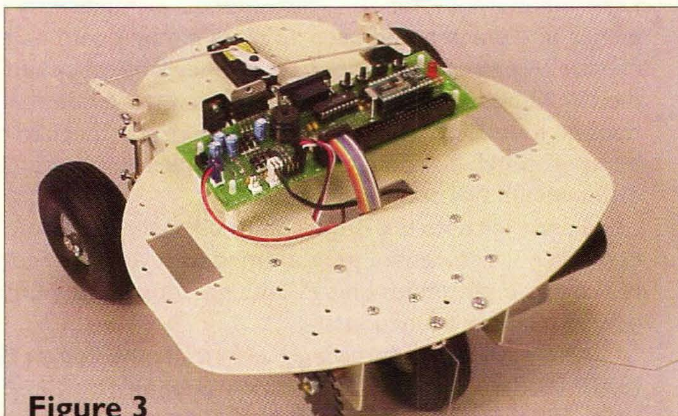

Figure 3

The ARobot, from Arrick Robotics, incorporates a single drive wheel, and dual steering wheels.

and are suitable for tasks where the robot must carry 25-35 pounds or more of weight.

As an example, the Max '99 kit ($229.00) is a dual-deck 12-inch diameter base, complete with heavy-duty motors, wheels, and support casters. Additional decks and risers can be purchased if you require more mounting space for electronics. Even larger is the Round Max '96, ($249.00) at 16-inches in diameter. The Zagros bases are constructed from black plastic.

Though Zagros specializes in bases, they also offer optional components, including motor drivers, ultrasonic sensors, and microcontroller boards. Zagros provides more of a "mix and match" approach to constructing a robot to your specifications, rather than theirs.

PPRK: Palm Pilot Robot Kit

www-2.cs.cmu.edu/~reshko/PILOT/

The PPRK — Palm Pilot Robot Kit — was developed by the Carnegie Mellon Robotics Institute. As its name implies, PPRK is designed to be used with a Palm Pilot as the main brain; you provide the Pilot. The kit includes a chassis, a trio of modified R/C servo motors and omni-directional wheels, and support electronics.

Besides using the Palm Pilot as a microcontroller, the PPRK is unusual in that it uses a three-wheel drive, rather than the more typical two wheels, with one or two undriven support casters. The three drive wheels are spaced 120 degrees apart from one another around the circumference of the robot's chassis. To make this odd configuration work, the wheels used with the PPRK are omnidirectional — they allow forward movement, as well as movement side-to-side. The base design is known as holonomic, and the PPRK is one of a small group of robots that can move in any direction.

Carnegie Mellon won't sell you the kit, but you can purchase it from Acroname, **www.acroname.com/**. Prices start at $265.00, and the kit is available in several versions. The Carnegie Mellon web site also provides full details if you want to build your own from scratch. Acroname — among others — sells the individual parts, including the omnidirectional wheels.

Robix/Advanced Design

www.robix.com/

Robix is more of a general construction set than a kit to build a specific robot. I'm including it here because of its unique ability to create all kinds of interesting robots, including walkers, grippers, and arms. The Robix kit includes machined metal links, six specially altered Hitec servos, and assorted hardware. The servos and links are connected very much like an Erector set, where parts can be joined to create a variety of joints and limbs.

The product is intended mainly for classroom instruction, though it's also great for garage-shop inventing. **NV**


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Jingxi Zhang, Yang Zhang, and Huifang Ni • Foster City, CA

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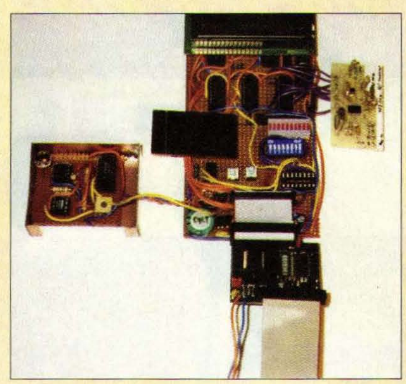
Henry Chan • New York, NY



In today's increasingly violent world, the threat of nuclear disaster becomes more real as terrorists go to great lengths to endanger the lives of numerous civilians in addition to their own. Nuclear attacks from the use of "dirty bombs" or even the use of nuclear weapons has caused society to think the unthinkable. The project presented here illustrates a robust early notification solution should there be any dangerous levels of radiation whether it be from a terrorist attack or simply leakage of radioactive waste. The Robust Remote Nuclear Radiation Monitor with Intelligent Power Management (NRM) allows a monitoring agency to quickly determine the levels of radiation in an area through a wireless radio link. The device uses the ultra-low power MSP430-1121 from Texas Instruments as the microcontroller, a silicon photodiode-based sensor, an LCD and two buttons for user interaction, an amorphous silicon solar panel and battery for power, and super-capacitors for energy storage. Thanks to the intelligent power management, the device can be used outdoors, as well as indoors in low-light levels, even without a battery. Low Power Mode 3 (LPM3) is used extensively in conjunction with a 32 kHz watch crystal as the source of timing interrupts. A sigma-delta ADC is implemented for accurate voltage measurements. The NRM calculates instantaneous counts per minute (CPM), as well as a moving average CPM. The highest level of radiation detected in the last 24 hours is also stored. The radio link using the TI TRF4400 ISM single chip 430 MHz transmitter allows quick notification of a possible danger. To provide confirmation of proper operation, the NRM transmits a heartbeat signal after every user-determinable time period. For survey use, the NRM can be configured to produce an audible click for every detected particle, as well as an audible alarm. This device provides the early warning necessary for the rapid evacuation of the affected area in the case of an emergency.

THIRD PLACE: EVENT RECORDER

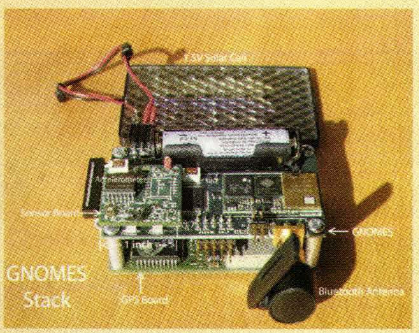
Sean K. Barry • Burnsville, MN

Our ER8XX device continuously records and monitors cardiac electrocardiogram (ECG) analog data, coming from electrodes and leads attached to a patient's chest. When the patient wearing the device feels a cardiac symptom (angina/chest pain, shortness of breath, palpitation, sweating, etc.), they can press an "EVENT Record" button on the front face of the device and it will record their ECG for one to three minutes. The ER8XX continuously acquires ECG data, so the recorded "ECG Event" spans a period of time both preceding and following the time at which the button was pressed.

Once "ECG Event(s)" have been recorded and stored in NV FLASH memory, the patient can press the "SEND Event(s)" button on the device and transmit recorded ECG data to a health professional monitoring them at a receiving station. This is done via an audio signal, which is output through a speaker into a common telephone receiver. Optional program selections allow the ER8XX to change the durations and types of recorded "ECG Events," to transmit at alternate speeds, and even to monitor the ECG signal continuously and "automatically" in Arrhythmia Detection mode (AD mode). Two key requirements of the ER8XX design require functions found only in a microcontroller from the Texas Instruments MSP430 family. First, the Low-Power Management functions and, secondly, the Clocking/Timer(s) functions of the TI MSP430. Together, they make possible solutions that aren't allowed by selecting any other microcontroller. Several other microcontrollers were examined as candidates for the ER8XX design. But, the MSP430 part has specific novel features, which make it perfect for the ER8XX design.

Honorable Mention:
GNOMES

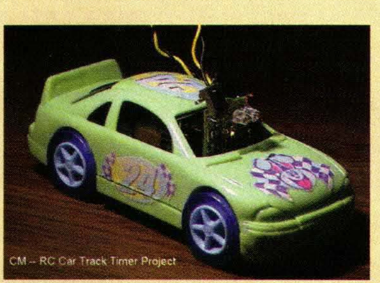
Jeremy Patrick Frantz • Houston, TX



The design goal of the Generalized Network Of Miniature Environmental Sensors (GNOMES) is to create a system of low-cost sensor nodes that are self-organizing and can work in a collaborative manner to solve a given problem. Cost and power consumption constitute the two overriding design constraints for this development effort. These constraints were based on the following assumption: traditional macro sensor devices are bulky and expensive, but extremely accurate. Because of the high cost per sensor, a single high-precision device is also not generally fault tolerant. Therefore, by flooding an application area with many small cheap devices, one can overcome the weaknesses that are inherent in this kind of system. Data collected from multiple sensors can be combined to improve the accuracy through the use of advanced DSP algorithms (e.g., creating a high-resolution image by combining multiple low-resolution images). The system is inherently fault tolerant because of the many nodes that are in use. If a few nodes become inactive, overall system performance should not suffer much.

Honorable Mention:
RC CAR TRACK TIMER

David Johnston • Westford, MA



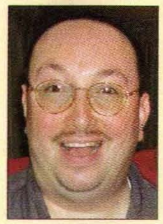
This system is to be used with RC Cars, Radio Controlled Scaled Racing. Set up at a racetrack, the system can monitor LAP timing and determine finishing order automatically with precision down to one millisecond. The system design has three basic components, the Track Gate (TG), Track Monitor (TM), and the Car Monitor (CM). Each of these three components has a single TI MSP430F11x1 microcontroller. Communication and synchronization between these three parts is done via standard consumer infrared (IR) components, remote control type. A CM resides in each RC racecar. It gets power from the car's battery, as well as monitoring the battery voltage. It receives IR signals from the TG to synchronize to the system, as well as detecting the Start/Finish line crossing. Once it crosses, it sends the crossing time and battery voltage to the TM via a Time Division Multiplexed (TDM) IR signal. The synchronization and TDM nature of this system allows up to 16 CMs to be active at a given time with each CM programmed to a different interval number. Even if multiple CM cross at the same time, they will transmit their true crossing time in an ordered fashion to the TM. There may be upwards of a half-second before a CM sends this data to the TM, but sends the true finish time with millisecond accuracy.

About the Judges ...

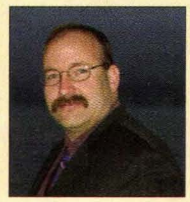
Dan Danknick works as an embedded-systems engineer specializing in high-speed communication firmware. He holds nine US patents for his work in industry which has included Canon, Walt Disney Imagineering, and Celerity. In his spare time, he works in the competition robotics industry as a supplier and TV technical commentator. He also volunteers yearly as a technical-support engineer for Dean Kamen's FIRST robotics competition.

Patrick Campbell (BSME Cal Poly 1993, San Luis Obispo and MSME Stanford University 1995) has been a product manager for a line of embedded-microcontroller products for Mosaic Industries. Currently, he works for Pace Technologies developing specialized lighting and camera equipment for the entertainment industry. For the past two years, he has been developing a 3D HDTV camera system that has been taken down to the Titanic and Bismarck wrecks. He has also been competing with fighting robots since 1994. Patrick can be reached at patrick@tmz.com.

TI/Nuts & Volts MSP430 Gadget-O-Rama Contest



Steve "Mouse" Silverstein is Sr. Animation Programming Systems Developer at Walt Disney Imagineering. During his nearly two decades as an "Imagineer" at Disney, Mouse has worked on innumerable projects at Disney theme parks around the world, including: the "Carousel of Progress" at Walt Disney World Magic Kingdom, "Body Wars," and the Norway Pavilion's "Maelstrom" attractions at EPCOT in Walt Disney World, the Pan Galactic Pizza Port," and "Splash Mountain" attractions at Tokyo Disneyland, and "Star Tours" at Disneyland Paris. His main responsibilities are in the design, development, and support of the proprietary hardware and software tools used in the programming and animation of Disney's Audio-Animatronics® figures and attractions. Most notably, his programming tools were used extensively for animating the hundreds of Audio-Animatronics figures at Disneyland Paris and the new Tokyo Disney Seas theme park in Japan.



Todd Mendenhall — Age 38 — Hometown is Rancho Palos Verdes, CA. Education: BSME Cal Poly SLO 1987 and UCLA 1999. Occupation: Aerospace Engineer specializing in altitude control (15 years). Projects: OMS-EP (NASA ozone mapping probe), KOMPSAT (Korean high-resolution imager). Other items: Four International patents, two US patents; Heavyweight Combat Robot Panzer has four event championships.

UNIQUE, LOW-COST, SELF-POWERED, PANEL-MOUNTED LED MINIMETERS

Panel-mounted LED minimeters replace fragile "analog-mechanical" and "expensive digital" panel meters that display current and volts in AC line applications. CUL Certified.

Model LM15: Integral display and current transformer, housed in a rugged water-clear polycarbonate shell less than one-inch square, provides display of AC load currents up to 15 amperes for either 50 or 60 Hz service. Five amp (LM5) and 20 amp (LM20) models are also available.

The display is self-powered so no additional or external components are required. No batteries or power supplies are needed to activate the display as it transforms a tiny portion of the load current to illuminate the display's colorful LEDs. LED segments may have custom-configured colors for volume orders.

The LM15 is C-UL listed/double insulated and available with CE marks to meet all safety requirements worldwide. Patent(s) pending.

A companion model VM120 provides a display of line voltage from 50 to 150 VAC.

All minimeters can be installed without tools. Electrical connections are made by quick-connect blade terminals and panel mounting uses a single brass spring retainer with an anti-slip feature for secure mounting.

Panel cut-out required is the standard square opening (0.97") as used for utility AC sockets. Any panel thickness from 1/32 to over 1/4 inch can be accommodated.

Intended to replace fragile analog mechanical meters and more expensive digital meters, these minimeter products provide rugged, accurate, low-cost alternatives (low-volume price $20.00, 10K pricing under $15.00) in a smaller package well-suited for these applications.

- Power Distribution Units (PDUs)
- Industrial Control Panels
- Service Panels
- Marine and Automotive Dashboard Displays
- OEM Product Panel Metering

For more information, contact:

Avatar Engineering Corp.
301 Newbury St. #200, Dept. NV
Danvers, MA 01923
978-590-7060 Fax **978-887-6275**
Email: **avatar1@avatarengineer.com**
Web: **www.avatarengineer.com/minimeters/**

WAVE CORRECTOR — TRANSFER VINYL RECORDS AND CASSETTE TAPES TO CD

Ganymede Test & Measurement announces a new release of Wave Corrector. This popular software package processes analog recordings from vinyl or tape/cassette sources for transfer to CD recordable media. The program integrates wave editing and noise reduction functions and runs on the Microsoft Windows 95/98/ME/NT/2000/XP platforms.

The new release incorporates many additions to enhance the usability of the program. Improved track editing features have been implemented together with new search facilities and display options.

Wave Corrector incorporates an advanced music restoration function which is designed to remove clicks and background noise while maintaining the musicality of the original sound. Damaged recordings are rejuvenated using a novel combination of analytic and heuristic procedures. By this approach, the program avoids many of the unpleasant processing artefacts common with competing systems.

A graphical overlay is provided that allows the user to compare the waveform before and after restoration. Interactive features provide the ability to audition and modify corrections, if necessary.

Wave Corrector also automatically finds track changes and assembles separate wave files representing each track of an album. Tracks can be easily split or merged and track boundaries can be customized to suit the user's requirements.

Visit the Wave Corrector website (**www.wavecor.co.uk**) for a full description of the program and to download a trial version.

Single-user licenses cost $45.00 US and include unlimited upgrades.

For more information, contact:

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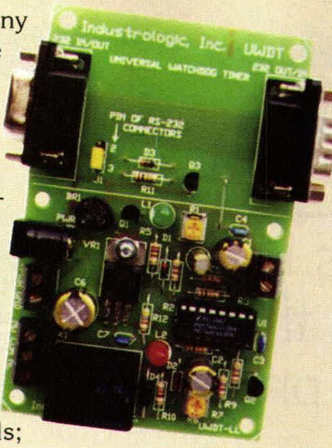
Holly Croft, Barrack Hill, Dept. NV
Coleshill, Amersham HP7 0LW
United Kingdom
Tel: **+44 1494 724362**
Fax: **+44 1494 723093**
Email: **derek@wavecor.co.uk**
Web: **www.wavecor.co.uk**

UWDT UNIVERSAL STAND-ALONE WATCHDOG TIMER

The Industrologic UWDT is a stand-alone watchdog timer circuit that can be triggered with logic level or open-collector digital outputs from a microcontroller or single board computer, or with RS-232 serial data from any communication protocol. It can be used to increase



the reliability of nearly any microcontroller or single board computer system by monitoring a signal, and activating a reset circuit or cycling the system power if the signal is no longer present.

The UWDT features are: Convenient screw terminal block connections for relay and digital trigger signals; DB9F and DB9M pin-to-pin connections provide pass-through for RS-232 signals; Jumper selectable monitoring of either RS-232 transmit or receive signal; Can be triggered by RS-232 data of any baud rate; 10 amp Form "C" relay with connections to all contacts; LED indicators for trigger and relay activation; Adjustable time periods for both trigger frequency and relay on time; On-board power supply for all circuitry; and pin-type power connector for easy connection to wall block power supplies.

The UWDT is shipped complete with all items necessary to begin using it immediately: The UWDT circuit board; a serial port cable for connection to a PC-compatible computer; a wall-block power supply; and a hardware reference manual.

For more information, contact:

Industrologic, Inc.
3201 Highgate Ln., Dept. NV
St. Charles, MO 63301
636-723-4000
Email: **info@industrologic.com**
Web: **www.industrologic.com**

TINYIR TRAINABLE IR REMOTE CONTROL RECEIVER

Adding IR remote control to your next project or to an existing one, just got a whole lot easier.

With TinyIR, just apply power, train the chip to recognize the codes you want to use, and you're ready to go. Code patterns are safely stored in internal non-volatile EEPROM. The chip can be re-trained many times, if needed.

Features: Trainable — use it with a remote you already have; Control signals are usable directly — four or eight pulse or level outputs available; LED indicator — flashes when a valid command is received; Small size; and IR sensor can be mounted remotely, for more flexibility

By installing one or two external passive components, you can configure 0, 1, 2, 3, or all four of the outputs as momentary, and the rest as toggle. Momentary outputs pulse high for approximately 100 mSec when their code is recognized. Toggle outputs change state when their code is recognized.

If you need more than four outputs, add an expansion chip (a standard 74HC259) to get eight outputs. You can configure 0, 1, 2, 3, 4, 5, 6, or all eight outputs as momentary, and the rest as toggle.

Based on an eight-pin Microchip® PIC 12CE519 CMOS microcontroller with EEPROM, this device has been developed to work with most modern IR remote controls. It supports bi-phase, pulse width, and pulse position encoding techniques. All four or eight codes must be in the same "family," such as a number of different keys on the same remote would be.

For more information, contact:

TauntonTek
609-953-5519
Email: **grieb@pics.com**
Web: **www.pics.com/~grieb/IR.htm**

by Steve Russell

The High-Roller — PIC-based Electronic Dice

Stack the odds in your favor with this MCU-based project

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!

Introduction

Having been professionally involved in circuit design many years ago, I recently found myself longing for the unique odor of smoking flux and the burnt fingertips gained while soldering a small component into a circuit. A quick scout around the web showed that many people are now using microcontrollers (MCUs) to implement logic, and that the development tools needed are often free or relatively cheap. Since I also enjoy low-level programming, this was too good to pass up, and I resolved to dip my toe back in the water with a small MCU-based project.

After further research, I decided to use a Microchip **(www.microchip.com)** PIC MCU. These are very popular, and the company provides lots of information and tools such as the MPLAB assembler/simulator environment, all available at no cost from their website. If you've not used a Microchip MCU before, writing code for them is very easy. Devices such as the PIC16F84A are used in countless projects that can be found all over the web. A user forum called the PICList **(www.piclist.com)** is another useful resource if you need some guidance or help.

Not wanting to create yet another electronic thermometer, I decided to design an electronic dice roller, which I call the High-Roller. Nostalgia played a part in this decision, since a 7400-series-based die was one of the projects I built when first getting involved in electronics. While choosing an MCU, I was particularly attracted to the PIC12C508A, because it packs a lot in a very small chip.

The '508A is an eight-pin MCU with 512 words of program memory, seven control registers, and 25 registers for program use. Its instruction set comprises just 33 different opcodes. Six of the '508A's pins can be configured as I/O lines if your design is able to use the chip's internal 4MHz oscillator instead of a more stable external crystal or resonator. This allowed me to keep the circuitry very simple (see Figure 1), and focus on becoming familiar with the programming of the MCU.

One drawback of the '508A is that it is a one-time programmable (OTP) chip, rather than being flashable

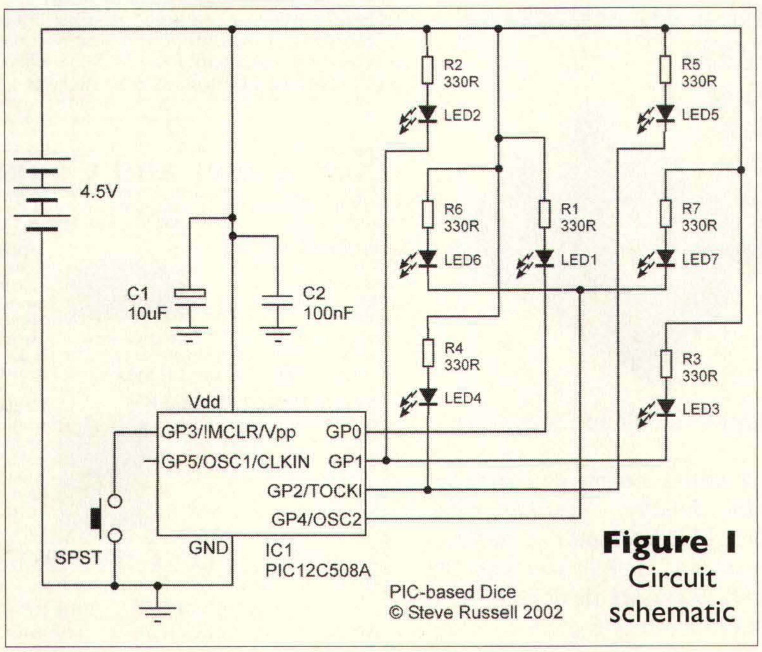
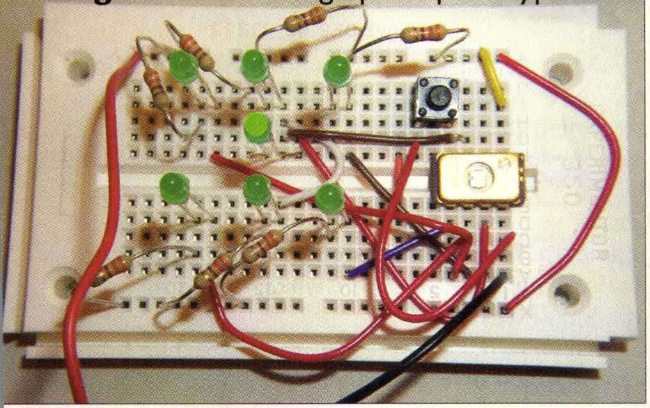


Figure 1 Circuit schematic

Figure 2 - Photograph of prototype



like the 'F84A. If there's a bug in your program, you need a new chip! For development purposes, therefore, Microchip offers a UV-erasable part, which I used to debug the High-Roller, switching to an OTP part for final construction.

Two other important limitations of the '508A are limited stack size (two words), and no support for interrupts, but I saw these as a challenge!

User interface

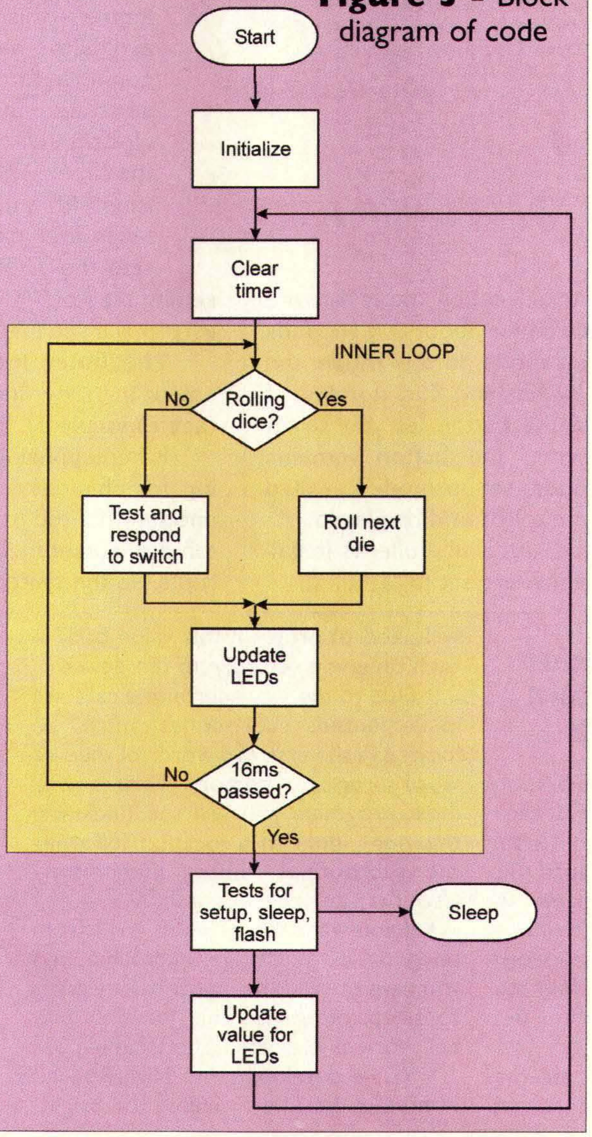
For output, I decided to use the time-honored seven-LED way of representing numbers on a die, shown in the prototype in Figure 2. By switching on the appropriate LEDs, the dot pattern for each value from one to six is displayed. My project from all those years ago rolled a single die, but a programmable design can easily be made to roll multiple dice. The High-Roller allows up to seven dice to be rolled simultaneously.

You press the single button to roll the dice, indicated by flashing the display between "3" and "reverse 3." The device has to be responsive, that is, the dice should roll as soon as you press the button, and this is covered in some detail in the code description. After rolling, the results are displayed by showing the values for individual dice sequentially. Note that two consecutive dice with the same value have to be easy to discern. This is achieved by fading the LEDs up from off to full brightness for each value to be displayed.

After displaying all of the dice, the LEDs are flashed between "2" and "reverse 2" and the dice are displayed again. Unless the button is pressed again, the High-Roller switches off after five such display sequences. This puts the '508A into its sleep mode, with all LEDs extinguished. Almost no current is drawn while asleep, so no power switch is required. You wake the High-Roller up by pressing the button, which displays the results of the last roll again. This means that there should be no arguments about what was rolled!

Set-up mode — The final interface

Figure 3 - Block diagram of code



Tools for Construction

Construction is straightforward, just make sure you get the polarized components the right way round. Putting the LEDs in backwards will not cause a component failure, they just won't light up. Getting the tantalum capacitor reversed may cause it to fail, and putting the PIC in backwards will almost certainly blow it, and render it useless.

Note that you will need a device programmer to program the PIC12C508A. A quick Google search found many sites from which you can purchase relatively cheap programmers (<$100.00, some much less). My own programmer is a Galep-4 from **www.conitec.com**, which is not cheap (at about $300.00), but it programs a whole variety of other devices in addition to the smaller PIC MCUs. Its software is included in the purchase price, and is regularly updated to add new devices (currently about 2,000 are supported). I have no connection with Conitec other than as a satisfied customer.

Tools for Debug

No special tools are needed for debug. A multimeter is useful for checking voltages, but an oscilloscope is not needed (it is fun to watch the pulse width modulation used to control the brightness of the LEDs, though!). If the device doesn't work after you have built it, there are three main possible causes:

1. Power not applied. When you first apply power, you should see the initial "double-1" roll. If not, check that the PIC is receiving the correct voltage on its power and ground pins. (You did insert it the correct way round, didn't you?)

2. A fault in construction or a faulty component. Check that all connections are correct and look out for short-circuits and open-circuits. Check component polarity (polarized capacitors, LEDs, PIC), and that the switch pulls the PIC input pin to ground when depressed.

3. A faulty PIC12C508A. Use the verify function of your programmer to make sure the device is correctly programmed. Make sure you double-check the polarity of the power supply before inserting the chip in the circuit. You may want to use a socket to make this easy to do. If you bought your PIC from me, it was verified and checked for correct operation before being shipped to you. Use proper anti-static handling techniques before touching the device.

```
==================
Example 1

;**************
; INNER LOOP
;
;   This main loop is repeated over and over for about 16ms. Loop execution
;   time creates latency in detecting the end of the 16ms period, so keep
;   it as short as possible. TMR0 is clocked each 128us, so the path MUST
;   be shorter than this to avoid missing timer comparisons.
;
;   Cycle counts:
;
;   1.  Longest path through loop code is 88us.
;   2.  Shortest path through loop code is 24us.
;
;   Worst case timing error in exiting loop is therefore 88/16384,
;   or about 0.5%.
;
;**************
loop
     btfsc          dicestat,S_ROLL ; [1/2] Test if we're rolling the dice
     goto rolldie   ; [79a max] YES: Roll die (skip switch testing)
     call switch    ; [50b max] NO: Poll the switch

;**********
; Test if it's time to turn the LEDs on
display
     movf ontime,w  ; [+1] Get the time the LEDs should go on
     subwf          TMR0,w    ; [+2] Subtract w from timer
     movlw          LEDOFF    ; [+3] Assume we're switching the LEDs off
     btfsc          STATUS,C  ; [+4/+5] Carry flag=1 if ontime=<timer
     movf ledval,w  ; [+5} ...so time to switch LEDs on, get value
     movwf          GPIO               ; [+6] Switch LEDs on/off as reqd.

;*****************
; End of inner loop
loopend
     btfss          TMR0,7    ; [+7/+8] bit7=1 after 128 counts
                               m b  =28 $ 9 28  as> 6   ppr x 1        1
```

decision was to allow the user to select how many dice are rolled. Holding the button pressed for about two seconds puts the High-Roller into set-up mode. In this mode, the number of dice is indicated by flashing that number of LEDs. Subsequent presses of the button let you select from one to seven dice. When the button remains unpressed for about two seconds, set-up mode is exited and the new number of dice are rolled and displayed.

When power is first applied, the High-Roller is initialized to roll two dice, both of which are set to "1."

Code description

A high-level block diagram of the code is shown in Figure 3. Let's take a look at the overall flow, examining the main areas in a little more detail as we go. Along with the excerpts included here, the full code is available from the *Nuts & Volts* FTP Library. As timing is crucial, many of the source code comments contain a number in square brackets, indicating cycle counts, which I used for calculating execution times.

When a reset occurs — due to either power being applied or a button press waking the device up — a '508A status bit informs you which of these it was, so you can tailor the code to handle the needs of each situation. Much of the initialization is common, and — most importantly — the code sets some configuration options using the OPTION register of the MCU.

In particular, weak pull-ups are applied to all inputs — this allowed me to leave GP5 floating, and avoids the need for a resistor to pull up the switch connected to GP3. The MCU is also set to wake up when an input pin changes state; its internal 4MHz clock is selected, and a 1:128 prescaler assigned to the timer, TMR0. The 4MHz clock means the MCU runs with a nominal 1us cycle time, since one cycle takes four clocks. A 1:128 prescaler for the timer sets the TMR0 register to increment every 128us, setting bit 7 of TMR0 after a little more than 16ms, which, as you will see later, is an important part of the design.

The inner loop — After clearing TMR0, the code enters the inner loop, which is the heart of the program (see Example 1).

It is responsible for updating the display and checking for changes in the switch, and has to do so often enough that the user perceives that responses to the button are instantaneous. The '508A does not support interrupts, so the switch has to be polled.

Things to note about the PIC12C508A and other comments

• An individual oscillator calibration value is stored at address 0x1FF in each '508A during manufacture. If you wish, you can (as in the High-Roller) load this value into the OSCCAL register to ensure reasonable accuracy of the internal clock. For OTP parts, check your programmer information carefully to make sure you don't overwrite this value when programming. For UV-EPROM parts, be sure to read out the calibration value before erasing, as you will need to program this value back in each time you re-program the device.

• Due to the way subroutine calls are implemented, subroutines must be located in the first 256 words of the 512 word program memory. This is why most programs you will see (including this one), jump to a location following the subroutines almost immediately after the start address of 0x00.

• If you want the '508A to wake from sleep on a pin change, Microchip says you have to read the inputs before going to sleep, otherwise this function may not work as expected. See Example 3.

• While developing the High-Roller, I wanted to be able to adjust the brightness of the flashing LEDs (during a roll and at the end of a display sequence) without having to carefully check all through the code. A simple macro (Example 4) made this possible.

• To take the picture shown in Figure 2, I removed the light-proof cover from the window of the '508A (a thick piece of sticky card) so you can see the UV window. Interestingly, the flashgun caused the device to reset itself — you can see the first "1" being displayed. Microchip recommends that you cover the window, since light can clear internal registers, leading to unpredictable results and great difficulty in debugging your application.

A status byte (dicestat in the code) contains flags that control program operation. One of these flags (S_ROLL) indicates whether or not the dice are being rolled. If they are, execution is transferred to the rolldie subroutine (see Example 2) using a goto to help avoid stack problems and to allow the code to skip the call to switch by using goto display when returning from rolldie. Switch presses can safely be ignored while the dice are being rolled. While using gotos is often frowned upon in programming circles, they are sometimes necessary, and can be efficient when used carefully.

Rolldie rolls just one die each time it is called, making three calls to a linear feedback shift register (also in Example 2) to generate a pseudo-random number between 0 and 7. LFSRs have the advantage of being quicker to execute than many other common random number generators. Values 0 through 5 represent die values of 1 through 6, so values of 6 and 7 are discarded and the same die is rolled again next time around the inner loop.

Successful throws are saved in the appropriate variable using the indirect (FSR) register, and pointers are updated to roll the next die when rolldie is called again. When rolldie detects that the currently-selected number of dice have all been rolled, S_ROLL in dicestat is cleared to return to normal display mode.

Testing the switch — If the dice are not being rolled, then the High-Roller is going through the normal display sequence, and a call to switch is made. Switch is quite complicated since it has a lot to do. Its main role is to test for changes in the button status. If the user presses or releases the button, the code reads the value of TMR0 and saves it for later. On subsequent calls to switch, the button is tested for further changes. Each time a change is detected, TMR0 is again read and saved.

If no change is detected, TMR0 is checked to see if 10ms has elapsed (defined as DEBTIME) since the last transition. In this case, the new state of the switch is recorded in dicestat (S_PRESS flag). Note that all four possible transitions are decoded: released-released, released-pressed, pressed-released, and pressed-pressed. This avoids any problems due to switch bounce, very fast button presses, or transitions while S_ROLL is set, and also simplifies the wake-from-sleep code.

Action is only taken for released-pressed transitions, all others are discarded. When the High-Roller is in set-up mode, each press cycles the number of dice to be thrown from 1 to 7 and round again. More often, however, the High-Roller is displaying the previous throw and the dice are rolled. Rolling even seven dice takes place very quickly, usually less than a millisecond or so — exactly how long depends

```
==================
Example 2

;*********************************************************************
; LFSR
;
;    This subroutine uses a 16-bit linear feedback shift register to
;    generate a pseudo-random sequence of bits. The feedback has been
;    selected to give a maximal length sequence.
;
;    INPUT:        FSR points to a register which will receive the next
;                  random bit.
;
;    OUTPUT:       The register pointed to by FSR is shifted left. Bit7
;                  is shifted into the C flag, bit0 receives the new bit.
;
;        Effect on shiftreg:
;        new bit15 = old bit15 XOR old bit14 XOR old bit12 XOR oldbit3
;        new bit14:0 = old bit15:1
;
;    Cycle count: 18 (inc 2 for call)
;
;*********************************************************************
lfsr clrf feedback          ; [1] Initialise feedback bit
     movlw       1          ; [2] Bit 0 of W used to XOR
     btfsc       sr_hi,7    ; [3/4] xor in bit15
     xorwf       feedback,f        ; [4]
     btfsc       sr_hi,6    ; [5/6] xor in bit14
     xorwf       feedback,f        ; [6]
     btfsc       sr_hi,4    ; [7/8] xor in bit12
     xorwf       feedback,f        ; [8]
     btfsc       sr_lo,3    ; [9/10] xor in bit3
     xorwf       feedback,f        ; [10]
     rrf feedback,f         ; [11] Feedback bit to C flag, bit 7 is x
     rrf sr_hi,f    ; [12] Shift it into the high byte
     rrf sr_lo,f    ; [13] ...and the low byte
     rlf INDF,f     ; [14] Shift o/p bit into FSR->dice reg
     retlw       0          ; [16]

;*************************************************************
; ROLLDIE
;
;    Rolls a die pointed to by FSR.
;
;    To roll a die, this routine calls lfsr three times to generate a number
;    between 0 and 7. If a 6 or 7 is rolled, the FSR reg and rollctr are
;    not adjusted, so that the same die is rolled next time. If the roll is
;    good, then FSR is increased to point at the next die, and the roll
;    counter (rollctr) is decreased. If rollctr gets to zero, all dice have
;    been rolled, so we clear the S_ROLL flag and set variables for the
;    next display sequence.
;
;    INPUT:        FSR points to the die being rolled
;                  rollctr has to be set to the total number of dice to roll
;
;    OUTPUT:       FSR->die receives a number between 0 and 7
;                  0 and 5, representing dice throws of 1 through 6.
;
;    Cycle counts (inc 2 for call):
;    1. Roll 0-5, more dice to roll                    65 cycles
;    2. Roll 0-5, last die                                 78 cycles
;    3. If the roll is a 6 or a 7                          62 cycles
;
;*********************************************************************
rolldie
     clrf INDF              ; [1] Clear the die register
     call lfsr              ; [19] Shift in the first bit
     call        lfsr              ; [37] ...and the second bit
     call lfsr              ; [55] ...and the third bit
     movlw       6          ; [56] Maximum value we allow is 5
     subwf       INDF,w     ; [57] ...so subtract 6 and test if -ve
     btfsc       STATUS,C          ; [58/59] Test carry flag
     goto display   ; [60] If set, rolled 6 or 7 so go round again
; Roll was good, so move to next die
     incf FSR,f             ; [60] Rolled 0-5 so bump FSR
     decfsz      rollctr,f ; [61/62] Set rollctr=rollctr-1
     goto display   ; [63] Done? NO: Go round again if not done
;*********
; All dice have been rolled, set up for display
     bcf dicestat,S_ROLL    ; [63] YES: Clear the roll flag
     call setdice   ; [72] Reset pointer and counters
     movlw       SLEEPCNT  ; [73] Get the number of display cycles
     movwf       dispctr   ; [74] ...before sleep and set dispctr
     goto display   ; [76]
```

```
==================
Example 3

; YES: We have displayed SLEEPCNT times.... time to sleep
      movlw        LEDOFF   ; We want LEDs to be switched off while asleep
      movwf        GPIO              ; ...so set outputs to switch them off
      movf GPIO,w  ; Read port before sleeping (as per Microchip)
      sleep                          ; ... and goodbye!
==================
Example 4

;*********************************************************************
; MACROS
;*********************************************************************
mSET_ONTIME        macro     val
  if val == 0
      clrf ontime
  else
      movlw        val
      movwf        ontime
  endif
      endm

==================
```

on how many invalid throws are generated. To give the user an indication that a roll has occurred, switch also sets S_FLASH to trigger the roll flash sequence, which lasts for about a second, after which the new results are displayed.

Driving the LEDs — The final part of the inner loop is the code to drive the LEDs. A variable (ontime) is tested against the current value of TMR0. While the timer is less than ontime, the LEDs are kept switched off. When the timer reaches a value greater than or equal to ontime, the LEDs are switched on by setting the GPIO port to the value held in ledval. Ledval and ontime are set in various places to control what is displayed on the LEDs. A subroutine (getgpio) is available to convert dice values to their corresponding port drive values.

The end of the inner loop has a test to see if bit 7 of TMR0 is set, which occurs some 16.4ms after the timer was cleared. If you recall, TMR0 is clocked every 128us, which is therefore the limit of the longest path through the inner loop code to avoid missing TMR0 values. The longest path is actually 88us (see Example 1), so the design has a comfortable margin.

Out of the loop — After about 16ms, execution leaves the inner loop and a series of tests are performed to determine whether:

- Two seconds have passed, and so a change to the set-up status is needed. If set-up mode is entered, ledval is set to the number of dice, and ontime and flashtmr are used to make the LEDs flash this value.
- The device is flashing the LEDs to indicate a roll or end-of-display sequence. If so, ontime sets the brightness, and flashtmr controls the period and duration of the flash sequence.
- To continue displaying the same die, ontime must be moved earlier to make the LEDs a little brighter the next time through the inner loop. The LEDs are kept off the first time through the loop, then ontime is reduced by about 0.25ms each iteration, until the LEDs are on for the whole 16ms of the loop. This means that the LEDs display each die value for approximately (16/0.25)*16ms, or a little over one second.
- Maximum brightness has been reached. If so, it is time to display the next die.
- Five display cycles have occurred and it is therefore time to switch off the High-Roller. If so, the LEDs are switched off and the sleep command puts the '508A into low-power standby mode. As I mentioned earlier, the High-Roller configures the chip to wake up when the button is pressed. Other triggers — such as a watchdog timer — are available, but not used in this design.

The tests are performed in this order, so that, for example, going into set-up mode takes precedence above all else. Depending upon the outcome of these tests, the values of status bits in dicestat, and setuptmr, ledval, flashtmr, ontime and other variables are set as necessary for the next pass through the inner loop.

At the end of this section of code, control returns back to the top, where the timer is reset and the inner loop is executed once again.

Debugging and design changes

Debugging a design based on the '508A is a challenge, particularly since I don't have access to any sophisticated hardware aids, such as an in-circuit debugger. However, careful use of the MPLAB simulator, coupled with close observation of the behavior of the buggy code, was sufficient to enable effective debug.

When I started this project, I had no feel for how much code would be required in the inner loop, so the TMR0 prescaler was initially set to 1:256. When I found I could perform the necessary function in less than 128us, I was able to change the prescaler to 1:128, which also reduced the total loop time from 32ms to 16ms.

Parts List

The parts are all very easily sourced from vendors such as Digi-Key, Newark Electronics, and Future Electronics. For development purposes, the UV-erasable (JW) version of the PIC12C508A is harder to find in stock, but both Digi-Key and Newark Electronics carry it.

R1-R7 — 330 ohm, 1/8W resistors, or use a seven-resistor R-pack
LED1-LED7 — General-purpose LEDs. I used 3mm, green LEDs
IC1 — PIC12C508A microcontroller
C1 — 10uF tantalum capacitor
C2 — 100nF capacitor
SPST — Single-pole, single-throw push to close switch

This also improved the display quality by eliminating a pronounced flicker. Making this change turned out to be fairly straightforward, and I believe this was primarily because I resisted the temptation to use numeric constants. Instead, I defined symbolic constants and variables. These, coupled with a logical structure, made the change simple to implement.

The last change I made was to put in an additional call to lfsr at the top of the outer loop, just before clearing the timer. While debugging, it was useful to have a repeatable series of "random" numbers following a power-on reset. Once the code was working, however, I wanted to eliminate this way of generating a repeatable series of rolls. Calling lfsr every 16ms makes the numbers generated depend on exactly when the button is pressed, which is essentially random when done by a human!

Conclusion

To be satisfied that the High-Roller was giving a fair roll to its dice, in the guise of an exercise in statistics, I convinced my children to tally some 1,200 rolls of the dice. The results were as follows (1-6): 202, 178, 205, 234, 180, 201. A colleague of mine did some analysis which indicated that the dice do, indeed, appear to be fair.

To make the High-Roller usable, I packaged the electronics and a battery-holder for three AAA cells in a small candy container, and designed a suitable graphic to go on the front of the unit. You can see the finished device in Figure 4 — the push button is between the two words on the graphic.

I had great fun designing and debugging the High-Roller, and learned a lot about the MCU. Now I have to think up a new project (I'm determined not to design a thermometer!). I hope you enjoy either making your own High-Roller or get interested enough to design your own devices, too. **NV**

About the author

Steve Russell started out his working life as a hardware design engineer. Somewhere along the way, he was seduced by computers, and began designing subsystems of various types for them, working for a multi-national computer company. Much later, after a spell in development management, he decided that salespeople needed his help and so he moved into technical marketing. He still misses the baleful green glow of an oscilloscope in a darkened lab, late at night ...

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by Danny R. Graves

Modifying a Tridon EP35 Turn Signal/Hazard Light Flasher to Flash Your Brake Lights

All it takes is a little knowledge, minimal sweat equity, and a few dollars' worth of electronic components ...

Many people flash their brake lights by manually pulsing their brake pedal, in order to get more attention from the driver of the 10,000 pound SUV approaching them from behind.

There are several companies offering aftermarket electronic modules to automatically flash brake lights. Some of these modules flash the brake lights as long as the brake pedal is pressed while others flash for a few seconds then stay on continuously. These modules typically cost anywhere from $30.00 to $50.00.

By modifying the electronics of a Tridon EP35 turn signal/hazard light flasher, you can get the same function for less than half the cost. In addition, you will be able to tailor the function to your liking.

How do the EP35 and other flashers work?

The EP35 flasher has three pins: battery, ground, and load. Battery and ground connections are obvious. The load pin is connected to the lamps. The connections are usually labeled as E for ground, B for battery, and L for load on the flasher base.

Federal Motor Vehicle Safety Standard (FMVSS) 108 S5.5.6 requires that failure of one or more turn signal lamps be indicated, except on various large vehicles 80 or more inches in overall width which use variable load flashers. It simply requires a significant change in flash rate when a bulb is defective. FMVSS108 does not require detection of lamp outage for hazard function.

Some flasher designs accomplish this indication by a fast flash of approximately 200 flashes per minute (FPM) while others do it by a constant-on (100% duty cycle) mode. Typically, electronic flashers indicate bulb failure by fast flash, while thermal flashers indicate the failure by constant-on. The normal (no bulbs defective) flash rate and duty cycle is 60 to 120 FPM and 30% to 75%, respectively. Unfortunately, most people don't know what it means when their turn signal starts flashing too fast or changes to a constant-on mode. Some mechanics even think the flasher module is defective when a bulb is out.

The type of flasher determines the method of detecting a defective bulb. There are several different types of flashers. There are thermal, mechanical, electromechanical, and electronic. The mechanical and electromechanical types are typically used on variable load vehicles, which means — per FMVSS108 — they do not have to detect a defective lamp. Thermal and electronic flashers are the types that have to detect a defective lamp.

Thermal flashers, which use a bi-metallic strip to open and close the flashing circuit, indicate a defective bulb by switching to 100% duty cycle. This is the natural way the thermal flashers behave. When a bulb is defective, there is not enough current flowing through the bi-metallic strip to heat up the metal sufficiently to cause the circuit to open. Therefore, when a bulb is defective, the other bulb just stays constant-on (when the turn signal switch is closed).

Detecting a defective lamp with electronic flashers is more complicated than with thermal flashers. Like all types of flashers, electronic flashers are typically very compact yet have to dissipate several watts of power.

Figure 1 shows an example of a Tridon EP35 electronic flasher. Electronic flashers have an integrated circuit (IC), which controls the function. Some typical manufacturers of these integrated circuits are Atmel, Motorola, and ST. The method of detection of a defective lamp (lamp outage) is similar for all the manufacturers. The integrated circuit that is used in a large number of flashers is the Atmel U643B. An examination of the lamp outage methodology of an Atmel U643B-based flasher module will serve as a good example for all flashers with similar integrated circuits.

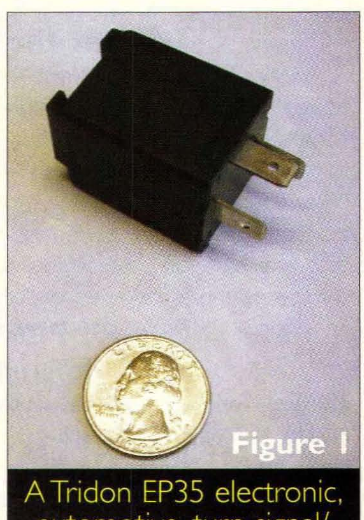


Figure 1

A Tridon EP35 electronic, automotive, turn signal/hazard flasher module.

The Atmel U643B

Brake Light Flasher

All you need is the basic flasher, the extra electronic components, copperclad board, a soldering iron, solder, and a Dremel tool or similar to break a trace on the printed circuit board. A multimeter would be helpful in order to check continuity in the circuit (especially to check discontinuity after a printed circuit board trace is broken), but is not really required. An oscilloscope is not required, but might be helpful to watch the charging and discharging of the capacitors. Programming is not required since the standard flasher ASIC is used.

The electronics are pretty simple. The only reason it is a "2" instead of a "1" is because of the mechanics of having to tap into the existing circuit and then figure out a way to piggyback the "add on" electronics (on the copperclad board) to the flasher without electrically shorting anything out.

IC requires a shunt resistor in series with the load and connected between pin 6 and pin 7 of the IC. The voltage drop across this shunt resistor is compared with the control signal threshold of the IC. Pins 4 and 5 are the timing component (resistor, capacitor) connection points, pins 2 and 6 are the battery voltage connections, pin 3 is the oscillating output to the relay, and pin 8 is the start signal input. When the IC detects that a bulb load is connected — via pin 8 — the IC starts to operate the relay. See Figure 2 for the IC pin-out.

At 12V, the nominal control signal threshold is 81 mV. This means that when enough load current is present to keep the voltage drop across the shunt resistor greater than 81 mV, the flash rate will be normal. However, when the voltage drop across the shunt resistor drops below 81 mV, the flash rate will approximately double. The U643B flashing frequency is set by an external capacitor and resistor. Most applications require the flash rate to be set around 90 FPM. The duty cycle is not adjustable by external components. The duty cycle range is 47% to 53%. However, in reality, most U643Bs have a 53% duty cycle.

Flasher applications are typically 2/4 or 3/6. This means two turn signals and four hazard bulbs or three turn signals and six hazard bulbs. The shunt resistor value must be selected depending on the type of application. The flasher may have to detect when one out of two bulbs is defective or one out of three bulbs is defective. For a 2/4 application using a U643B IC, a typical shunt resistor value

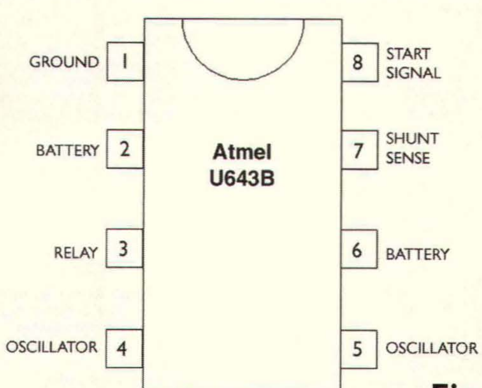


Figure 2

Atmel U643B IC.

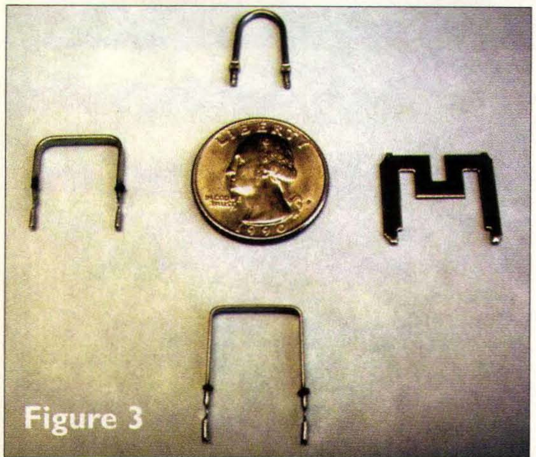


Figure 3

Several examples of automotive flasher shunt resistors.

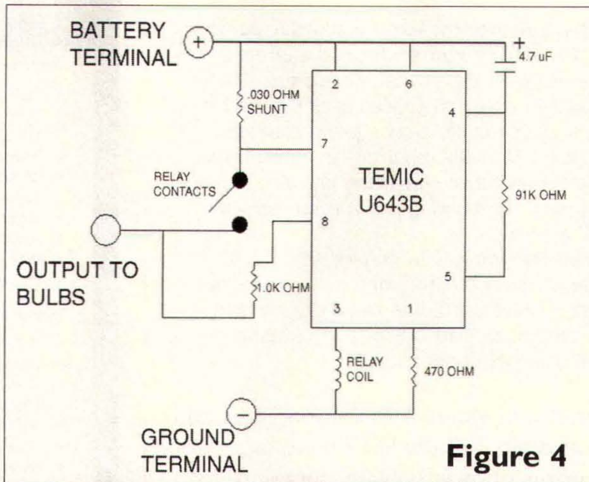


Figure 4

Stock Tridon EP35 schematic.

is 30 mW. For a 3/6 application, a typical shunt resistor value is 15 mW. Figure 3 shows several examples of shunt resistors used in automotive turn signal hazard flashers.

The stock EP35 schematic is shown in Figure 4. The 4.7 uF capacitor and the 91k resistor control the normal mode (no bulb out) flash rate. Increasing either the resistor or the capacitor will cause the flash rate to decrease. Decreasing either the capacitor or resistor will cause the flash rate to increase.

Modifying the EP35 to flash brake lights

You can install an EP35 turn signal/hazard flasher to flash brake lights without any modifications to the electronics. However, the brake lights will flash continuously as long as the brake pedal is pressed. This may get the attention of the police and result in a ticket. This is especially true if you flash all the brake lights on your vehicle. Flashing of the main brake lights is probably illegal in most states.

It is my personal opinion that you should only flash the cargo high mount stop light (CHMSL). The CHMSL is the brake light that is mounted in your back window. This will get the attention of drivers behind you, but will not allow your vehicle to be confused with emergency vehicles. Also, if the brake light flasher fails, only your CHMSL light will be affected and not the main brake lights.

The EP35 modifications, shown in Figure 5, will result in the brake lights flashing approximately eight times at a rate of 220 flashes per minute, then turn on solid. This is true as long as the brakes have not been applied for 30 seconds or more. The flasher flashes at 220 flashes per minute due to the bulb current causing a shunt resistor voltage drop less than the IC control signal threshold. Actually, in the brake light flasher application, the shunt resistor can be replaced with a solid wire of the largest gauge that will fit into the shunt resistor printed circuit board holes. This is advantageous in order to reduce the heat generation inside the flasher.

If the brakes have not been applied for five seconds or less, the brake lights will not flash, but will come on solid. If the brakes have not been applied for between 5 and 30 seconds, the brake lights will flash between one and eight times, then turn on solid.

The circuit works by turning on the relay coil continuously after an amount of time that is set by R1 and C1. C1 is charged by the oscillating signal coming from the IC. This oscillating signal is what causes the relay coil to turn on/off flashing the lights. When C1 charges sufficiently, the Q1 transistor turns on. When Q1 turns on, this turns on Q2 and applies the positive battery connection to the relay coil. When the positive battery connection is applied to the coil by Q2, the relay stops oscillating and stays on.

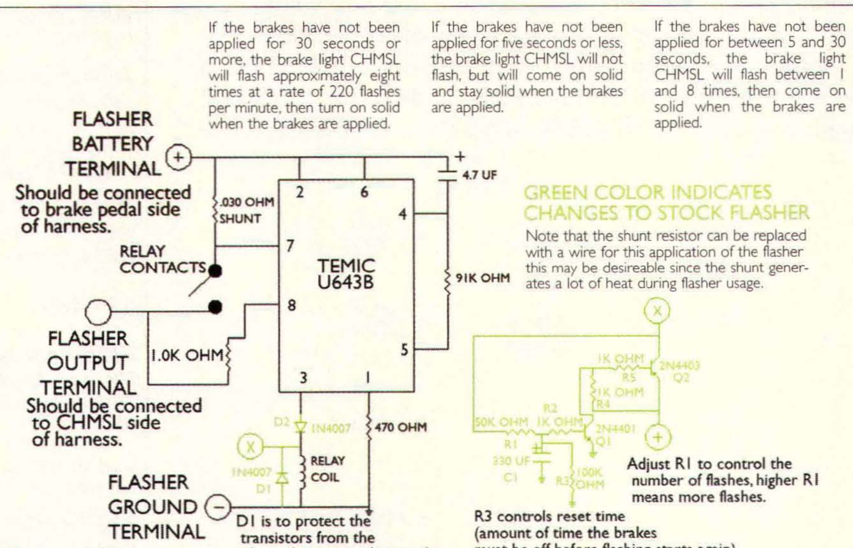


Figure 5

Modifications to the Tridon EP35 circuit to flash brake lights.

The relay remaining on causes the bulbs to stay on solid.

To add D2, the printed circuit board trace from the IC pin 3 to the relay coil positive side must be broken. This can be done with a Dremel tool or a similar device. The solder mask coating can then be scraped off the broken trace ends with a razor blade. The D2 diode leads can then be soldered between the broken trace ends. The D2 diode blocks the positive voltage — supplied by Q2 — from being shorted to ground by the IC.

The R3 resistor can be adjusted to change the amount of time the brakes must be off before flashing resumes. R1 can be adjusted to control the number of flashes. Increasing R1 results in more flashes since this increases the time it takes for the capacitor to charge.

D1 is to protect the transistors from the reverse voltage spike generated by the relay coil. The integrated circuit has built-in protection so the diode is not required in the stock EP35 circuit.

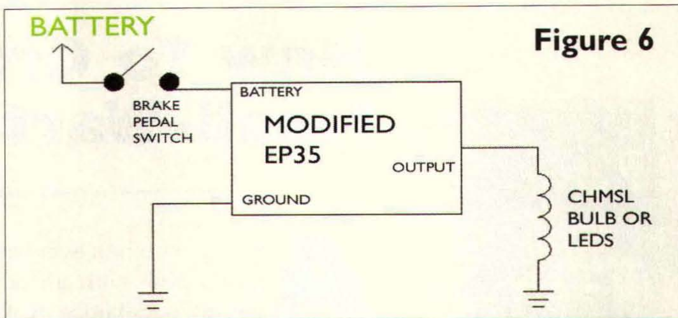
The cost of the Tridon EP35 flasher is around $10.00 at an automotive supply store. Even if you buy low quantities from Digi-Key, the cost of the additional electronic components required to modify the EP35 circuit is only about $2.50 (there may be minimum order requirements). Therefore, the total cost of the brake light flasher is around $12.50. This is less than half the cost of most commercially available brake light flashers.

The system connection is shown in Figure 6. Basically, you just install the brake light flasher between the brake pedal switch and the CHMSL.

Conclusion

Flashing of the brake lights definitely gets more attention from the drivers behind you. This enhances your safety, especially if you are on a small vehicle such as a motorcycle. Several aftermarket companies are offering brake light flashers at a cost of $30.00 to $50.00. With a little knowledge, minimal sweat equity, and a few dollars worth of electronic components, you can modify a $10.00 Tridon EP35 turn signal/hazard flasher to function as a brake light flasher. The user of this information must assume all responsibility of legal and safety implications of using such a device. **NV**

Figure 6



System connection of the brake light (modified EP35) flasher.

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by Steve Daniels

How To Craft A Small-Wart

Anyone who has ever tried to power a piece of high-gain audio gear with an ordinary department-store power supply — called a "wall-wart" — knows that the results are usually awful. Because wall-warts are designed to be sold as cheaply as possible, they contain only the barest minimum of filtering. The ripple current that gets through shows up in an audio output as hum — unpleasant at best, and often intolerable. The solution for powering many portable audio devices is a power supply that is well-filtered and tightly regulated — a Small-Wart.

This Small-Wart is designed to supply 7.5 to 9 volts of DC, at up to 60 mA. That's as close in smoothness to battery power as you are likely to need. While it can be used with many consumer audio products, I have incorporated design features that recommend it specifically to electric guitar players who need to power a variety of sound effect pedals ("stompboxes") in a stage environment.

Specifically, I have made it very physically rugged, and with a detachable AC power cable for easy storage in a gig bag. There is a "dead-battery" output for powering some types of distortions, and the outputs are physically isolated from the chassis. This last feature is important so that different grounding requirements can be accommodated easily. It is also inexpensive, so that building more than one to power a board full of pedals is quite feasible.

Because it is powered from the AC line, the Small-Wart is not suitable as a first project for a complete novice. In particular, correctly making the connections to the primary of the transformer and insulating them carefully takes some skill. You should also have some experience with tooling and painting a metal case. If you have built a couple of simpler projects successfully and now want a line-operated power supply for them, the Small-Wart may be the ticket.

Tooling The Case

I built the Small-Wart into a cast-aluminum box that is commonly available by mail order. It has a screw-on lid, and its sides

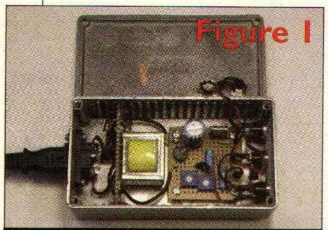

Figure 1

For safety and aesthetics, the mechanical design keeps penetrations of the case to a minimum. Primary power connections are carefully insulated, and separated from the low-voltage section.

Figure 2

The ribs on the end have to be ground down to create a flat surface.

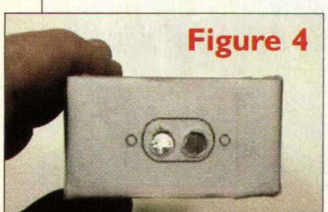

Figure 4

Start with two 1/4" holes.

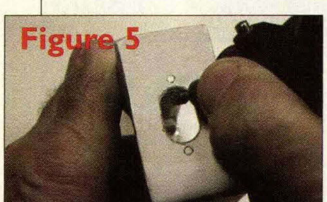

Figure 5

The opening can be enlarged with flat and round files, but a Dremel or similar rotary tool is preferable.

Figure 6

The AC inlet has to fit snugly.

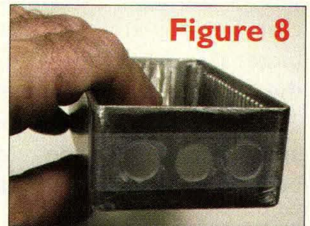

Figure 8

Seal the holes with clear tape on one side.

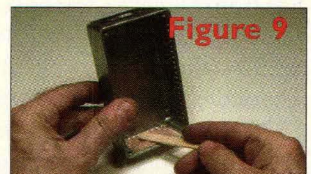

Figure 9

Filling with fiberglass auto body filler creates an insulated mounting surface.

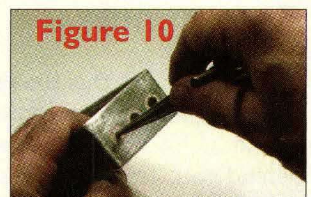

Figure 10

Drill and ream out the holes for the jacks.

Figure 11

The jacks are mounted temporarily to ensure that the surface is thin enough. Test with a meter to make sure there's no continuity to the case.

The hole for the AC power switch is located at the center of a line connecting the second ribs.

Figure 12

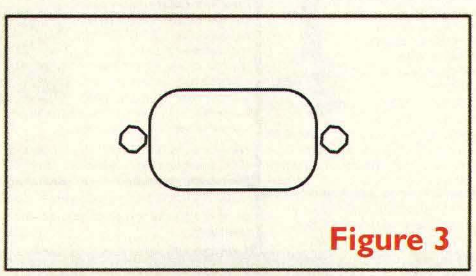

Figure 3

Use this template to drill and shape the hole for the AC inlet.

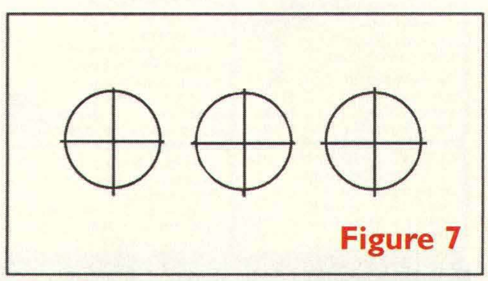

Figure 7

Use this template to drill and shape the holes for the power output jacks.

The Small-Wart isn't a complex circuit, but it is a power supply meant for road use; the builder has to be really anal about mounting, insulating, and fastening down. No test equipment is needed other than a DVM, but a good set of hand tools and some skill with crafting a metal chassis are musts.

are ribbed; this construction makes it both extremely strong and provides slots for mounting small printed circuit or perfboard assemblies. As you can see in Figure 1, I used the slots to hold a piece of perfboard on which the transformer is mounted. The board is secured with a few drops of epoxy cement, and the resulting assembly will take considerable abuse if it's built carefully.

Here is how I prepared the case: First, the ribs on both ends of the case have to be ground down for mounting the AC inlet and the DC output jacks. While this can be done with files, it's an awful lot of work; if you don't have a Dremel or similar rotary hand tool, I strongly suggest either borrowing one or using this project as a reason to give yourself a present. The drum-sander attachment shown in Figure 2 does this job in minutes.

The next step is to make the oval-shaped hole for the AC inlet. Cutting this accurately is essential, both for safety and esthetics, so I have specified a particular part for the inlet and created an actual-size drilling template. You can photocopy Figure 3 or download the JPEG from my web site.

Cut out the template, and tape it carefully to one end of the box. Drill two 1/4" starter holes, as shown in Figure 4. It is possible to do the rest of the cutting with files, but again, a rotary tool with a high-speed cutter (Figure 5) does it much more efficiently.

The power inlet should fit snugly into the cutout, and you can then drill the two holes for the screws that secure it (Figure 6).

Figure 7 is an actual-size drilling template for the holes for the output jacks. If you use the ones I have specified, three jacks will fit on the end panel. Fasten this template in place, drill out the holes with a 1/4" drill, and ream them to size. The holes are actually larger in diameter than the jacks, and you'll see why in a moment.

I created an insulated "platform" for mounting the jacks by back-filling the holes with fiberglass auto-body filler (Bondo is a common brand) and then re-drilling the appropriate-sized holes. To manage this, first prepare the end of the box by sanding it thoroughly on both sides and cleaning up with acetone. Then seal off the fronts of the holes with transparent tape as shown in Figure 8. Mix a small amount of Bondo according to the directions on the can and, as shown in Figure 9, spread it over the entire area. It must fill the holes and also cover the back to a depth of about 1/16". Let it cure overnight and then sand smooth.

Using a 1/8" drill and then a reamer, create the new holes for the jacks (Figure 10). Make sure that the jacks fit snugly. Sand the rear surface thin enough so that the bushings show, and you can screw on the washers and retaining nuts (Figure 11). Use an ohmmeter to make sure that there

Events Calendar

Conventions/ Hamfests

February 1-2, 2003
Tropical Hamboree® 2003. Fair Expo Center, 10901 SW 24th St. (Coral Way), Miami, FL. Dade Radio Club of Miami, Inc., Evelyn Gauzens, w4wyr @gzinc.com, 305-642-4139. John Hall, wd4sfg@bell south.net, 305-226-5346. **www.hamboree.org**

February 7-9, 2003
HamCation 2003. Central Florida Fairgrounds, 4603 W. Colonial Dr., Orlando, FL. Orlando ARC, Hal Prosse, 407-923-8699, kk1b@arrl.net. **www.oarc.org/hamcat/html**

March 29-30, 2003
Greater Baltimore Hamboree and Computerfest. Maryland State Fairgrounds, Timonium, MD. BARC, 410-HAM-FEST (426-3378). General Info: info@gbhc.org. **www.gbhc.org/**

May 2-3, 2003
Trenton Computer Festival™. NJ Convention Center, Raritan Center. Edison, NJ. KGP Productions, 1-800-631-0062. **www.tcfshow.com/**

May 16-18, 2003
Dayton Hamvention®. Hara Arena Complex. Dayton, OH. **www.hamvention.org/main .html**

June 13-15, 2003
SeaPac Ham Convention. Seaside, OR. Jim Schaeffer, 503-245-2518. **www.seapac.org /inform.htm**

Robot Competitions

February 21-23, 2003
Motorama Robot Conflict. Harrisburg, PA. emccarron@robotconflict.com **www.robotconflict.com**

April 13, 2003
Trinity College Fire Fighting Home Robot Contest. Hartford, CT. Jake Mendelssohn, jmendel141@aol.com. **www. trincoll.edu/events/robot/**

Complete Robot Competition List: **http://robots.net/rcfaq.html**

FIRST Robotics Competition

Regional competitions begin March 6-8, 2003.

FIRST Regionals

March 6-8, 2003
BAE SYSTEMS Granite State Regional. Verizon Wireless Arena. Manchester, NH.

March 6-8, 2003
Buckeye Regional. CSU Convocation Center. Cleveland, OH.

March 6-8, 2003
St. Louis Regional. St. Charles Family Arena. St. Charles, MO.

March 6-8, 2003
Virginia Regional. VCU Siegel Center. Richmond, VA.

March 13-15, 2003
Arizona Regional. Arizona Veteran's Coliseum. Phoenix, AZ.

March 13-15, 2003
Chesapeake Regional. US Naval Academy. Annapolis, MD.

March 13-15, 2003
UTC New England Regional. Meadows Music Theatre. Hartford, CT.

March 20-22, 2003
Central Florida Regional. University of Central Florida. Orlando. FL.

March 20-22, 2003
Great Lakes Regional. Eastern Michigan University. Ypsilanti, MI.

March 20-22, 2003
SBPLI Long Island Regional. Suffolk County Community College. Long Island, NY.

March 27-29, 2003
Canadian Regional. Hershey Center. Mississauga, ON Canada.

March 27-29, 2003
Midwest Regional. Northwestern University. Evanston, IL.

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is no continuity between the metal bushing of the jack and the box.

The last penetration of the case that is needed is the hole for the on-off switch. To locate this hole, screw the AC inlet temporarily in place. As shown in Figure 12, visualize a vertical line connecting the second rib on top and the second rib on the bottom. With a marking pen, mark a point at the center of this line, directly in front of the inlet connections.

Use a center punch or scratch awl to mark the center of the hole, and drill it. I have specified a subminiature switch that requires a 3/16" hole, and I strongly suggest using this particular one to conserve space. Make sure that the switch fits the hole snugly. Most people will want a pilot LED to indicate when the Small-Wart is on, so you should drill the hole for whatever bezel or LED holder you want to use. I located this on one side of the screw-on lid near the output jacks. The chrome bezel shown requires a 1/4" hole.

At this point — with all hardware removed — the case can be painted. I usually do it by sanding and cleaning up with solvent, applying a primer and then a couple coats of spray enamel, and baking in a small toaster oven that I keep for the purpose. You can find detailed "recipes" for finishing metal in many on-line DIY references.

Figure 13

Locking the threads of the screws.

Figure 14

A commonly-available miniature toggle switch is used, with its lever cut down.

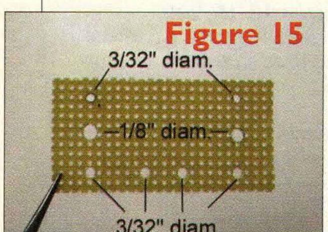


Figure 15

A small piece of perfboard is tooled to hold the transformer.

Putting It Together

The AC inlet goes in first. It is absolutely essential that this fixture be held rock-solidly in place and not have any "play" that would permit it to work its way loose when the power cord is inserted or removed. If you have a riveting tool, this is a good application for it. I didn't, so I created the equivalent of rivets by using solder to lock the threads of the two 4-40 mounting screws.

I have a 35-watt iron, and I heated each screw thoroughly with it before applying solder and let it melt into the crevices between the threads. When I was done, I used a cutoff wheel on my Dremel tool to shorten the screw ends and an abrasive stone to remove sharp edges. Wear goggles for this! The pieces can and do fly like bullets! Figure 13 shows the soldering process.

Carefully fasten a rubber foot at each corner of the bottom of the case. Install the switch, put your goggles back on, and use the cutoff wheel to shorten the shaft and an abrasive stone to remove sharp edges. The case should be able to stand on its feet now with the power switch in either position. Figure 14 shows what the result looks like.

The piece of perfboard that holds the transformer can be cut with a sharp scissor. I cut it 23 holes long and 11 wide. Figure 15 shows where I drilled the mounting holes and the holes for feeding the leads.

I prepared the transformer leads by splicing and soldering a 3-1/2" length of #24 wire to each bare lead and insulating each one with 1/16" heat shrink. Note that the center-tap wire on the secondary is not used, so it is cut off close to the body. To conform the heat shrink to the wire, I used a butane lighter that I keep available just for this purpose. Figure 16 shows the last splice before the heat shrink goes on.

The insulated transformer leads feed neatly through the holes in the board. As I did with the mounting screws for the AC inlet, I sealed the nuts to the screws by soldering them (Figure 17).

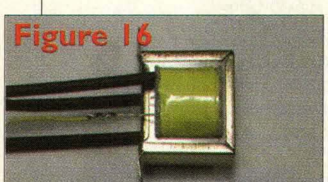


Figure 16

The transformer leads must be very carefully insulated.

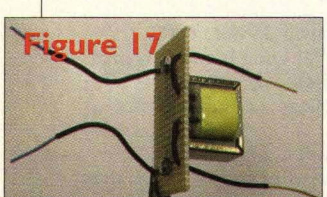


Figure 17

Feeding the leads through holes in the mounting plate keeps them in position.

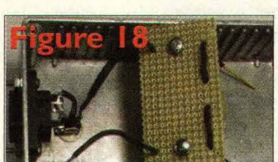


Figure 18

Beginning the wiring of the primary circuit.

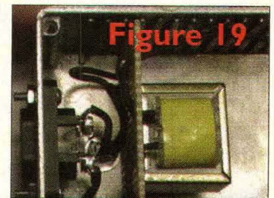


Figure 19

The primary circuit is done, and the transformer assembly can be locked in place with epoxy.

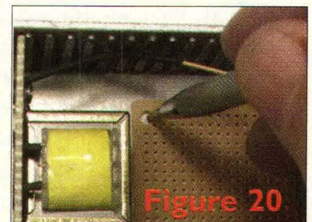
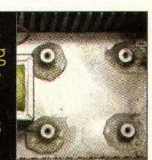


Figure 20

Locating the studs for mounting the PC board.

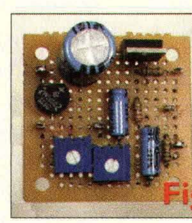
Figure 21

Getting ready to cement the studs in place.



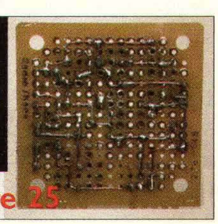
If you give it a clean mounting surface, epoxy cement will hold the studs securely.

Figure 22



Top of the circuit board.

Figure 24



Don't wrap leads around each other!

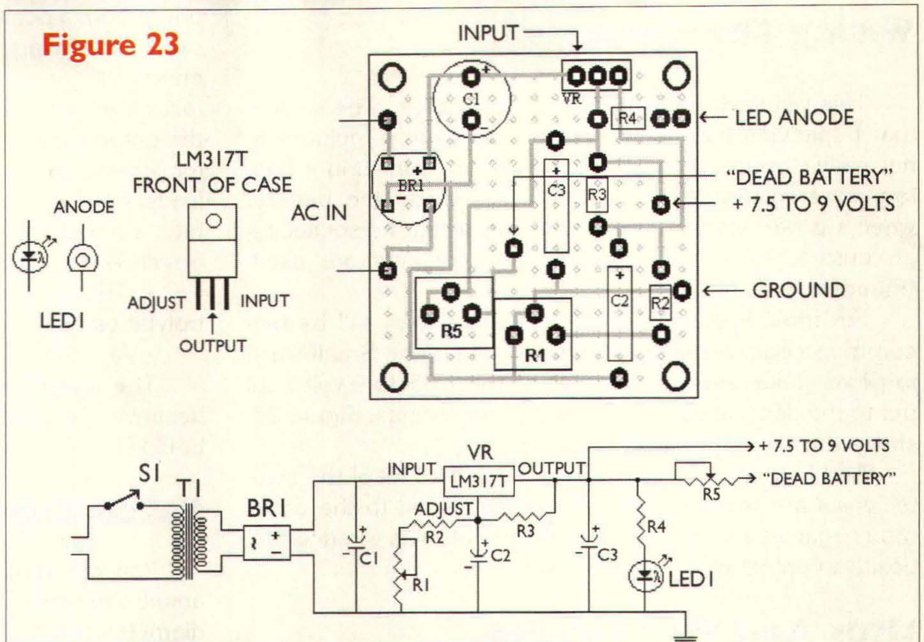
Figure 25

Wiring It Up

I soldered a short length of wire to one contact of the switch, covered it with heat shrink, and made the connection to one side of the AC inlet. Then I added an extra piece of heat shrink to one of the transformer primary leads before soldering the connection to the other switch contact (Figure 18).

The heat shrink slips over the switch contact and is conformed, heat shrink is added to the other primary lead and it is wired to the AC inlet. Before slipping the transformer assembly into place between the third and fourth ribs, I sanded in that area on each side and cleaned up with a Q-tip wetted with solvent. Then I inserted the transformer assembly and locked it in place by applying a few drops of epoxy cement on each mounting slot (Figure 19).

Figure 23



Here are the board layout and the schematic.

The rest of the construction is a lot easier, because it's on the low-voltage side. I built the circuitry on a standard piece of perfboard, which I located just forward of the transformer. I marked the locations of the mounting holes with a scribe as shown in Figure 20.

The circuit board is held in place by four threaded aluminum studs that are secured to the bottom of the box with epoxy cement. To get good adhesion, I prepared the locations where the studs mount by sanding lightly and cleaning up with solvent. Then I screwed the studs to the board as shown in Figure 21.

I cleaned the bottoms with sandpaper and solvent, applied a drop of epoxy cement to the bottom of each one, and gently set the assembly in place. When the adhesive had cured, I was able to remove the screws and reinforce the studs with more epoxy. The result looked like Figure 22.

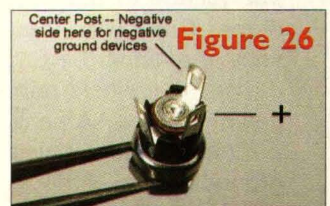
Next, I built the circuit board. Figure 23, (on next page), shows — in x-ray view — the layout that I used. I suggest that you stick with this arrangement, because it puts the inputs and outputs where they need to be and gets all the components connected without jumpering.

Figure 24 and Figure 25 show the top and bottom of the board.

When you wire point-to-point in this way on perfboard, do not wrap connecting wires around components; it wastes space and can cause shorts. Butt a connecting lead against the point to which you are soldering, hold it in place with locking tweezers or some other "third hand," and then solder. The points at which leads connect to off-board components are terminated with "flea" clips or other tie points. When done, the board is screwed down in the box and is ready for wiring and testing.

Testing

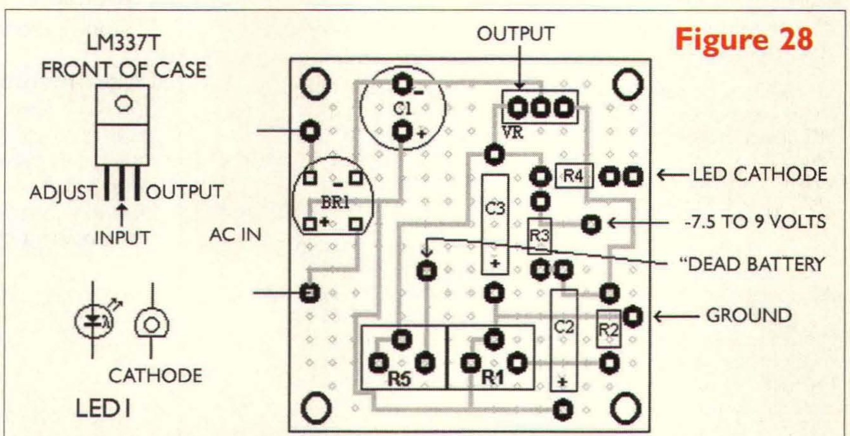
I did this before wiring the outputs. With the transformer secondary leads soldered in place, I connected a voltmeter between the +7.5- to 9-volt pin and ground. Then I plugged in the line cord and turned on the power. Rotating R1 with a screwdriver gave me the proper voltage range. I also checked for nine volts at the "dead battery" pin and made sure that I got illumination from an LED connected from the LED contact to ground.



We use the unswitched contacts for the output.

Beginning to wire the output jacks.

Figure 28



Layout of the positive-ground version.

Wiring The Outputs

This will vary some with your application. The socket that I specified has three contacts, because it includes a normally-closed switch. When the socket is used in a battery-powered device, the switch disconnects the battery when a power plug is inserted. We are using the socket as an unswitched output, so only two contacts are used (Figure 26).

For most applications, the center contact will be the common negative. Since I intended to use the Small-Wart to power guitar stompboxes, I wired the +7.5- to 9-volt output to the positive contact on two of the sockets. Figure 27 shows the wiring just after I started.

And Figure 1 was taken when I finished. All of the center posts are wired in parallel and connected to the common negative, and the "Dead Battery" output is wired to the positive contact of the third socket.

Uses And Possibilities

To anticipate a question: Yes, you can drop the output voltage to the six-volt range; just reduce R2 to 680 ohms. This lowers the voltage range to about 4.8 to 7.5 volts — making the Small-Wart useful for powering many devices that would normally require four of those always-getting-weaker AA penlights.

Many guitar players will want to create a positive-ground version of the Small-Wart for powering certain models of distortions, in particular, germanium Fuzz Faces and Tone Benders. To anticipate another question: You can't power both a positive and a negative ground pedal from the same Small-Wart; that would short the output. So I do recommend that you build a second Small-Wart if you use a mix of pedals with different grounding schemes. Yes, since the outputs are isolated, you can use the standard version for powering positive ground pedals by reversing the output leads. However, sooner or later, you are likely to want separate, dedicated units. The positive-ground version of the Small-Wart is built in exactly the same fashion, except:

- The polarities of the bridge rectifier and the electrolytic capacitors are reversed.
- An LM337T negative adjustable regulator is used.

The layout, shown in Figure 28, is slightly different, because the input and output pins are reversed on the LM337T.

Parts List — The Small-Wart

All fixed resistors 1/4 watt 5% tolerance	Suggested Mfr. Part Numbers
R1 - 500 ohm trimmer potentiometer	Mouser 72-T20YP-500
R2 - 1.1K	
R3 - 240 ohms	
R4 - 1K to 18K (see text)	
R5 - 200 ohm trimmer potentiometer	Mouser 72-T20YP-200
C1 - 1000 mFd 35-volt radial electrolytic	
C2, C3 - 10 mFd 16-volt axial electrolytic	
BR1 - 50 PIV bridge rectifier module	Mouser 625-W005G
VR - LM317T adjustable voltage regulator	
T1 - transformer, 117V to 12 VCT 60 mA	Mouser 41PG006
LED1 - see text	Mouser
S1 - SPST toggle switch	Mouser #10TC405
DC power putput jacks, 2.1 mm center	Mouser 163-4304
DC power plugs, 2.1 mm center	Mouser 1710-2131
Case	Pro's Kit #125B (Jameco, Webtronics)
1/4" high x 4-40 threaded spacers	Mouser 534-1450A or Jameco p/n 143360
Square rubber feet	Mouser 517-SJ-5023
LED holder or bezel	
AC power inlet	Qualtek, Mouser 562-77001
AC power cable	Mouser 173-21101
Pad-per-hole perfboard	
Perfboard for transformer support	
Flea clips	
Heat shrink tubing - 1/16", 3/32", 1/8", 3/8"	
#22 gauge zip cord	
Hook-up wire	

Patch Cords

You will want to have a few of these available, usually about three-feet long. The specified plug has a 2.1 mm diameter inside, and it mates correctly with the output jack shown on the Small-Wart side. Depending on what you are powering, you may need a different type of plug on the equipment side. Since I use 2.1 mm power jacks on all my gear, I use the specified plugs and wire them shell-to-shell and center-to-center. The cable is a #22 zip cord that is commonly sold for connecting miniature speakers. Some brands ID the conductors with a stripe on one of the leads, while others have one tinned lead and one bare copper. Musicians will want to ID the plug barrels for easy tracing in stage environments, and this can be arranged either with colored heat shrink tubing or a liquid plastic/rubber coating such as is used to put handles on metal tools.

I used 1/4" heat shrink as an inner "jacket" and 3/8" material as an outer cover over the barrel. In order to pass the 1/4" material through the rear hole of the barrel, I had to ream it out slightly.

To use the liquid coating, I slipped a 1" length of heat shrink over the strain relief of a plug. Then I assembled it (pulling the heat shrink out the end with chain-nose pliers), cleaned it with a little alcohol, dipped and hung it according to the manufacturer's instructions, and let it harden overnight. Cut off the closed end, and you have a professional, close-fitting result. **NV**

Acknowledgements and References
To R. G. Keen, for inspiring the project and suggesting the use of the rubber coating on the plugs. His article at **www.geofex.com** explains the theory behind the "dead battery" output. To Mark Hammer for looking over the original prototype and suggesting a number of valuable design ideas, and to the crew at **www.diystompboxes.com** for their support and interest.

A complete kit containing all of the listed parts (including assorted colored heat shrink, wire, and plugs for three patch cords) is available for $44.95 plus $5.00 shipping in the US. Checks or money orders to:
Small Bear Electronics
123 Seventh Avenue #156, Brooklyn, NY 11215
Or PayPal to **smallbearelec@ix.netcom.com**. Rates for overseas shipping and prices of individual parts can be found on-line at **www.smallbearelec.com**.

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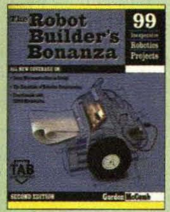

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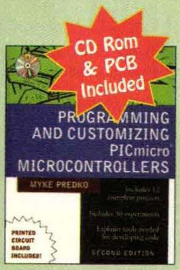

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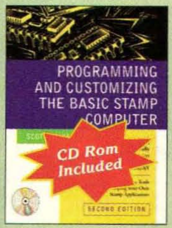

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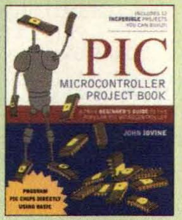

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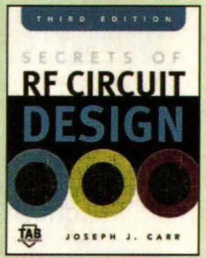

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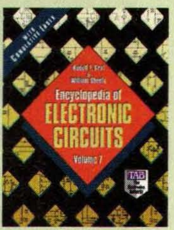

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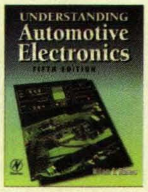

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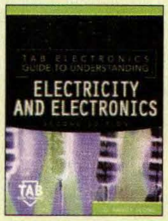

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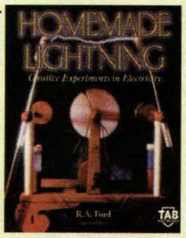

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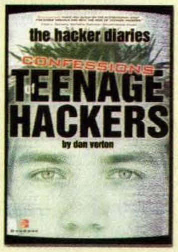

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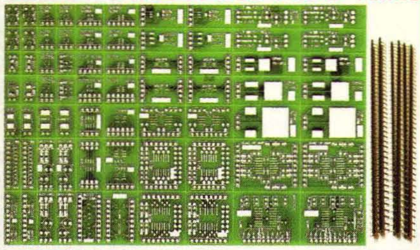

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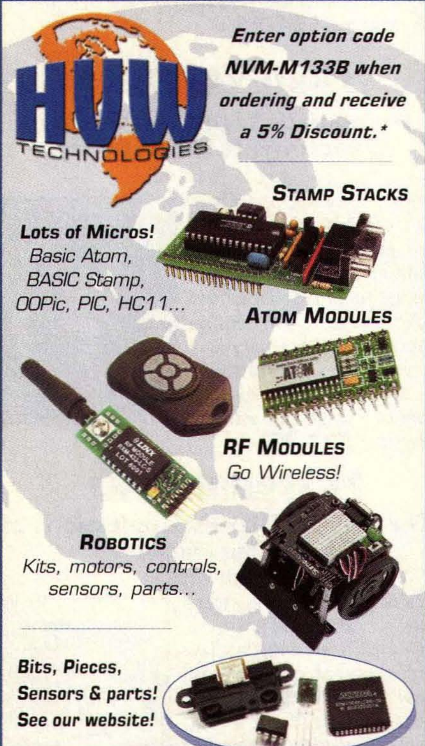

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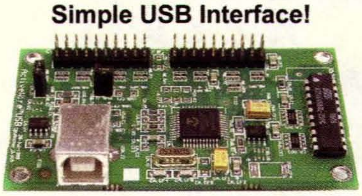

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An exciting look at the latest in what X-10 has to offer

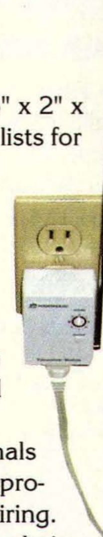
by Dennis Shepard

X-10 Has Gone Wireless

As an electrical contractor and licensed X-10 Pro Installer, I get to work with X-10 extensively. As the owner of Shepard Engineering Concepts, I've designed several X-10 interfaces including the X-10 Voice Recognition Control System in the Dec. 2000 issue of *Nuts & Volts* (which is available on the 'chalkboard' section of their website), and a Visual Basic computer interface which is located on my website @ http://home.att.net/~dennis.shepard.

As you might imagine, my home is fairly well-automated with X-10 and Voice Recognition technology. One of the nicest features, though, is the ability to do wireless X-10 including motion detectors, 2.4 GHz color video cameras, and VCR Commanders to record the action once the motion detector triggers it! So, let's get started with the basics and we'll go from there.

Wireless Transceiver Interface



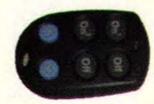
1

X-10's model #TM751 (Figure 1) is a 3" x 2" x 1" device which plugs into a wall outlet and lists for $12.99 on X-10's website @ http://www.x10.com. Located on the front is a 16-position rotary switch for the 16 different House Codes A-P. Also located on the front of the unit is an ON-OFF push-button switch which switches up to a 15-amp load using a two-prong socket located on the bottom. On the right-hand side is a small telescoping antenna.

This device will receive wireless signals from the different devices and send the appropriate X-10 commands over the power wiring. The devices it will receive from include keychain remotes, motion detectors, slimline switches, and many others. This means it will send all X-10 commands such as Channel #, On, Off, Brighten, Dim, All Lights On, and Everything Off for whatever House Code it is set for!

The TM751 will also respond directly from any wireless device set to Channel 1 and its House Code. This means that anything plugged into its two-prong socket can be controlled on Channel 1 of *any* wireless device with the same House Code. This transceiver and another wireless device may be all you need. Now ... let's take a look at a few of those wireless devices which are available from X-10.

Wireless Field Devices



2

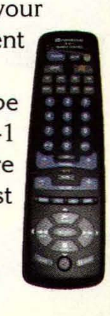
There's much to choose from here! To start with, X-10 makes a SlimFIRE Keychain Pocket Remote model #KR19A (Figure 2) for $19.99. It attaches to your keys and slips into your pocket or purse. It has two consecutive channels for ON-OFF control and has Brighten and Dimming functions, as well.

It can be set for any House Code and Channel #, the only restriction being that Channel 2 is automatically and always one number above Channel 1. In other words, if Channel 1 is set for 4 ... Channel 2 is automatically set for 5. That's not much of a restriction and seems to work out quite well. This would be a good place to recommend a practical application for this device.

Simply replace your light switch in your garage with an X-10 lamp module, install your TM751 in a convenient location, and you can use the keychain remote to light your garage at your convenience. Garage door openers are nice, but sometimes you need a lot more time or a lot more light. I've got four 100-watt incandescent lamps in my garage because sometimes I need that much light. However, not at 5:00 AM when I take my kids to daycare. That's when the Dimmer function really comes in handy!

3

Next on the list is the SlimLine Wall Switch model #SS13A (Figure 3), also for $19.99. It consists of a standard-sized switchplate that controls three channels, as well as Brighten and Dimmer functions. It 'sticks' to the wall with two self-adhesive pads located on the back of the unit. And it's only about 1/4" thick and uses a 'large calculator style' battery which slips in the bottom! Did you ever want a light switch on the wall next to yer' bed? Well, here's your chance! It's programmable as well for different House Codes and Channel #'s.



4

X-10 even makes what many consider to be the ultimate remote control unit, the 8-IN-1 Learning SuperRemote model #UR24A (Figure 4) for only $24.99. This is one of their best bargains in my opinion since it incorporates remote control of TV, VCR, Cable, Aux 1, Aux 2, CD, Digital Satellite

Systems, and X-10 controls. They've got a pretty fair listing of the 'codes' for various devices, so programming is easy! Once again, all these wireless devices require the TM751 to receive their signals and control the various X-10 devices in your system.

5

Let's Get Into Motion

X-10 has two different models of their 'Hawkeye' series motion detectors. There's an indoor unit model #MS13A (Figure 5) for $19.99 and a weather resistant outdoor model #MS14A (Figure 6) for $24.99. The indoor unit is white and the outdoor unit is a charcoal grey color. Both units are identical in appearance and function except for their environmental ratings.

6

A red LED is located at the top of each unit and a green LED is located inside the translucent 'window' which uses 'passive infrared detection' to operate. Unlike ultrasonic motion detectors, these units don't emit any signals and therefore can't be detected beforehand! That's kinda' important if you're using them for security purposes. More on that later in the article.

Inside each unit is a compartment for two 'AAA' batteries and two small push-button switches labeled as HOUSE/ON and UNIT/OFF. These switches will allow you to program all the features you want. The default setting is House Code 'A' and Channel 1. The unit also contains a photocell to allow detection 24 hours/day or dawn/dusk.

The default setting is to detect motion all the time. It can also be set to control using the photocell only. And it has a programmable time delay for 1-256 minutes after it stops detecting motion before it sends an OFF command. Like I said before, all the programming features you want! And you can even replace your keychain remote for your garage, if you so desire.

On With The Show

7

Miniature surveillance cameras are nothing new to electronic enthusiasts. However, what's new are the features they carry. X-10 has got to have some of the most visionary engineers, because everytime I look at their website, they've come up with another good idea!

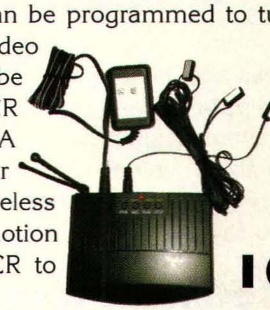
The 2.4 GHz Instant On Color Camera model #XC18A (Figure 7) with programmable power supply is available for $69.99. However, there are lots of 'package' deals available. One of my orders included the camera, pan-n-tilt base, motion detector, and receiver for only $79.99.

8

There are two different receivers available for the X-10 cameras. The small Video Only Receiver is model #VR36A (Figure 8) and sells for $49.99. It produces a composite video signal on a standard RCA phono jack. The Audio/Video Receiver model #VR31A (Figure 9) outputs both composite video and a modulated RF signal for Channel 3 or 4. It also outputs a monaural audio output signal. Oh, by the way, did I forget to mention the cameras have built-in microphones, as well! Sorry about that!

9

This would be a good time for another application scenario. The motion detectors can be programmed to turn on the power supply for the video cameras. And they can also be used to turn on the VCR Commander model #UX23A (Figure 10) which sells for $49.99. This unit accepts wireless signals directly from your motion detector and controls your VCR to enable it to record the action.



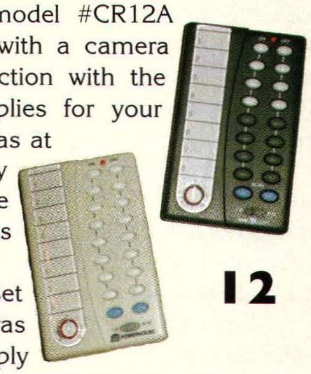
10

The unit itself has a small antenna on the back with connections for signal output and line power. It also operates on batteries. There's an LED on the back, as well, and is used to 'train' the unit to accept the PLAY, RECORD, and STOP functions from your VCR's remote. The top of the unit has push buttons for PWR, REC, PLAY, and STOP, as well as a red 'status' LED.

Basically, you select the function from one of the programming buttons on top of the unit, and program the Commander for that function by pressing the button on your VCR remote. It's stored in memory and is output to the VCR via an adhesive-mounted LED. The LED is 'stuck' to the front of your VCR's detector window (Figure 11), so it essentially mimics your VCR's remote via X-10 control.

11

Now, if you've got multiple cameras, X-10 has got something else for you, as well. The Camera Control System Remote Control model #CR12A (Figure 12), which came with a camera package, works in conjunction with the programmable power supplies for your cameras. Up to four cameras at a time can be controlled by the unit. And they can be scanned automatically, as well.



12

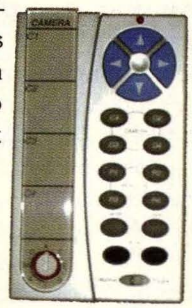
Essentially, the unit is set up to program your cameras as Channels1-4. You simply select the Channel # you want and the unit will turn on the one selected and turn the other three OFF. You can also program your cameras as Channels 5-8, 9-12, and 13-16 to use them in a separate scan sequence.

Ninja Pan-n-Tilt

The Ninja Pan-n-Tilt Camera Base model #VK74A (Figure 13) for $79.99 is just about the coolest thing you've ever seen! It's an accurate servo-controlled positioning system for mounting to an X-10 camera. It will rotate 240 degrees and will tilt up and down 130 degrees. It comes with the Pan-n-Tilt Remote Control model #CR14A (Figure 14) which lets you control the system.

13

You can use the four blue buttons to manually select the view, or you can actually program it to go to specific positions and scan to those positions automatically. You can do so much with this unit, that I'm not even going to try to describe all its features. Suffice it to say ... you won't be disappointed.



14

Software And Systems

At this point, just about anything you might imagine can be done with X-10 devices. The PC Video/USB Adapter Kit model #VA11A sells for $69.95 It's used with the Pan TiltPRO, WebView, MultiView, and Xray Vision software packages. It simply plugs in between your receiver and USB port of your computer.

The Pan TiltPRO software package goes for $49.95 and includes a model #CM19A PC Transceiver as part of the system. They offer a package deal which includes the PC/USB Video Adapter for $99.99. This system allows you to access up to four cameras and use the Ninja Pan-n-Tilt system over the Internet. It even allows virtual ZOOM with 100-400% scaling and requires a 10-digit code AND password to view, so it's pretty well encrypted.

The MultiView software goes for $99.99 and includes features like monitoring four cameras simultaneously and full screen zooming of any camera. And you can set it up with motion detection to record images every two seconds for 20 seconds, for example. Complete with time and date stamp! Hardware requirements also include a TM 751 Transceiver module and a Firecracker PC Interface model #CM17A.

The WebView software is an upgrade to the MultiView and sells for $79.99. As its name states, it's an Internet version of the package. You can also send commands to your other X-10 devices in your home over the Internet. It's quite a sophisticated package for the money.

The Firecracker PC Interface model #CM17A sells for $49.95 and includes a Palmpad Remote, PC Interface, a lamp module, and a Wireless Link Module. You can control everything from the Palmpad or your PC. Additional software is the MacroRecorder which lets you issue a series of commands, record them, and play them back as a single command. Pretty neat stuff!

And last but not least, the X-Ray Vision software for $69.99. It lets you view a single camera in real time over the Internet. But it's expandable to view up to 16 cameras by turning on and off the programmable power supplies. And the images can be updated every 10 seconds of real time. That's pretty fast over the Internet.

But this is only the beginning. Build your own system and before you know it, you'll be ready to have the automation of your dreams in your own home. And that's something to dream about! **NV**

***Next month,** look for Michael Gardi's article on adding a web interface to your X10-based home control system.*

Win a Free Copy of Final Cut Pro 4.0

Dr. RawStock has launched a contest to give away Apple Final Cut Pro 4.0 upgrades. "We thought it would be fun to launch a contest where the prize was a yet-to-be-announced piece of software — Final Cut Pro 4.0 — which has been shrouded in secrecy and hidden away in the vaults in Cupertino, CA. We'll give five lucky people a complete 4.0 upgrade when it becomes available. Our contest is simple; guess the date when you think Final Cut Pro 4.0 will be announced. The first five people to guess the actual date or closest to the date will win," said Lowell Kay, Dr. RawStock's President.

The Contest

Enter the contest on the company's website: **www.drrawstock.com**. The contest will continue until February 28, 2003. Complete contest rules are available on the entry form.

Never Get Stuck in Traffic With New Real-Time Traffic Product

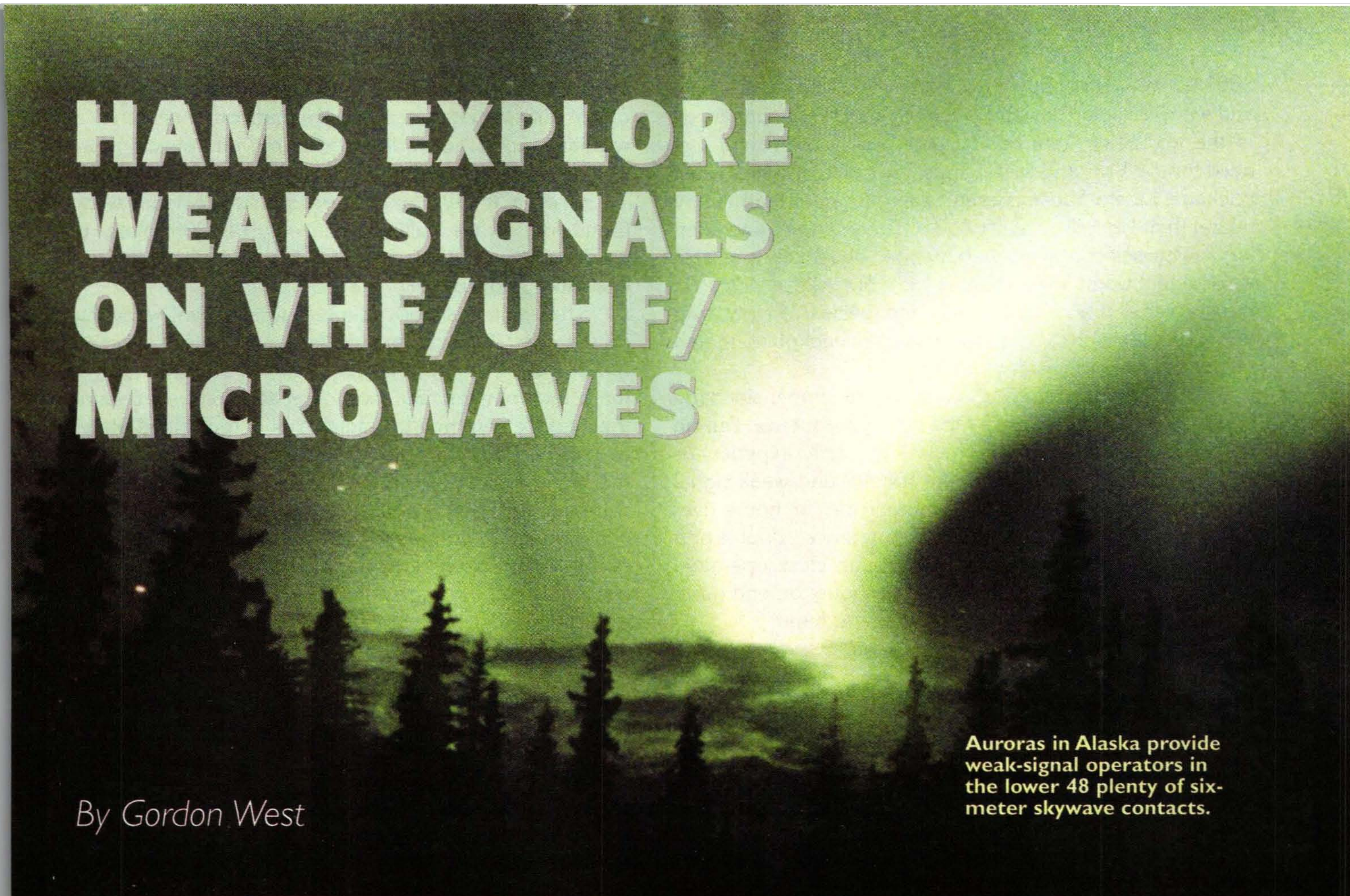
A new real-time navigation product by Mapopolis.Com, Inc., could virtually eliminate time spent waiting in traffic jams for its users. The new product actively searches for accidents, slow downs, and construction on the user's route and re-routes them, if necessary to avoid it. The new product will be available to consumers in the first quarter of 2003 ($19.95 per month). It is a turn-key, PDA-based solution including real-time traffic and navigation for all major US metropolitan areas.

"You may never have to wait in traffic again," said Mapopolis.Com, Inc., Vice President, Jeremy Straub, "while the product can't predict — or prevent — traffic problems, as long as the accident has been there for a few minutes, you most likely won't have to wait for it."

The software doesn't just avoid accidents though, it determines the best way to get you there — be it navigating around the accident, or waiting for it. The software incorporates proprietary new routing technology developed by Mapopolis. When an accident is detected, the software alerts the user and, depending on user-configurable parameters, will either present alternative routes or begin automatically providing new instructions.

The new product builds on the existing Mapopolis Navigator for Pocket PC and Platinum +GPS products currently available from the company, and includes complete US map coverage along with the real-time traffic data.

HAMS EXPLORE WEAK SIGNALS ON VHF/UHF/ MICROWAVES



By Gordon West

Auroras in Alaska provide weak-signal operators in the lower 48 plenty of six-meter skywave contacts.

Explore the long-range voice and data capabilites in the weak signal portion of the radio bands.

Ham operators who have passed "only" the Technician class no-code license are discovering there is a lot more excitement out there than just yakking back and forth over an FM repeater. Someone has told them there are all sorts of long-range voice and data capabilities in the "weak-signal portion of the bands." You know, the very bottom of the six-meter band, the two-meter band, the 222 MHz band, the 430 MHz band, and even excitement at the top of the 1.2 GHz band. No repeaters and definitely no FM!

The bottom of the VHF, UHF, and microwave ham bands is where weak-signal operators congregate and pull off some exciting long-range contacts. Instead of frequency modulation that is plagued with phase distortion over difficult paths and takes up a minimum of 10 kHz of bandwidth, weak-signal voice operation uses exclusively upper sideband. Typical bandwidth of a properly-modulated upper sideband signal is under 2.8 kHz, so noise is cut by 66 percent and your transmitter only puts out power on the syllables you modulate with your microphone. And to further reduce electrical interference from power lines and spark-plug noise from automobiles, weak-signal operators using upper sideband all employ horizontally-polarized antennas. For mobile operation, VHF and UHF loops are an effective way of radiating an omnidirectional signal, but polarized horizontally. For home station use, beam antennas are simply switched 90 degrees so their elements are parallel to the ground below.

One of the biggest boosts to the Technician class operator working upper sideband and data on the weak-signal portions of their bands is new multi-mode equipment from big name ham radio manufacturers:

- Alinco — HF + 6m
- ICOM America — HF + 6m + 2m + 430 MHz
- Kenwood Communications — HF + 6m + 2m + 430 MHz + 1.2 GHz
- Ten-Tec — 2m multi-mode
- Yaesu Vertex — HF + 6m + 2m + 430 MHz

Most of these manufacturers produce a 100-watt, high-frequency transceiver, and include multi-mode capabilities on six meters, two meters, and 430 MHz. The bigger units might also take a separate 1.2 GHz band unit, too. But what has probably attracted the most new hams to the VHF and UHF weak-signal portions of the band is the unbelievable low pricing of this gear, fostered by Yaesu Vertex and ICOM America waging a wonderful price war with the Yaesu FT-100 and the ICOM IC-706 MK IIG priced around $800.00 with included monthly free accessory deals. In years past,

$800.00 would only buy a two-meter/440 MHz weak signal and satellite radio. Now this price buys you 100 watts on all of the worldwide ham bands, plus more power than you need for the VHF and UHF bands, too, all in one nice, neat package. Lately, Yaesu is even adding more excitement by taking their HF + 6m + 2m + 430 MHz equipment and offering it with self-contained batteries for absolutely portable weak-signal work! Yaesu's latest HF + 6m + 2m + 430 MHz transceiver — the FT-897 — has capabilities of eight-amp hours of internal battery power, swell for backpacking and taking your comms with you.

On the six-meter band, weak-signal, upper-sideband voice is centered on 50.125 MHz calling frequency. During the winter and summer, six meters regularly experiences skywave refraction from the ionosphere, and weak-signal operators are easily able to communicate for hours over distances beyond 1,500 miles. Sometimes, double-hop skywaves will lead to no-code Technician class operators speaking halfway around the world for hours on end down at the weak-signal portion of the six-meter band.

6 Meters — A Guide To The Magic Band — a book authored by Ken Neubeck WB2AMU — explains all! (Worldradio Books, P.O. Box 189490, Sacramento, CA 95818; $12.00.) Weak-signal operators who really get serious about six meters may put up giant quad antennas and regularly work the world via daytime and evening ionospheric E-layer and F-layer refraction band openings.

On two meters, upper-sideband weak-signal work is found around the calling frequency 144.200. Many nets are found on 144.240 and 144.250, and all operators are exclusively horizontally polarized.

The excitement of two-meter weak-signal work might be the short-lived sporadic-E skywave contact over 1,500 miles. But these are rare occurrences, and they only last for a few minutes. But two-meter long-range excitement that is quite common throughout all of the United States is tropospheric ducting and weather front long-range contacts. As our atmosphere stratifies from a high-pressure, warm-air subsidence inversion, two-meter signals may get caught up in the tropospheric duct and travel for hundreds of miles. Approaching cold fronts mixing with moist warm air coming up from the south collide and may sometimes trigger two-meter paths that extend well beyond 1,000 miles!

And for those of you who live close to the Canadian border, ionospheric auroras will sometimes create powerful

MEGAWATTS TO MICROVOLTS AT HAARP

In Alaska, scientists beam megawatts into the ionosphere and measure the results in microvolts at their receiving stations. HAARP stands for High Frequency Active Aurora Research Program.

"The HAARP is committed to developing a world-class ionospheric research facility, consisting of a high-power transmitter system operating in the high-frequency range, and diagnostic instruments that will be used to observe the physical process that occurs in the ionosphere," comments Michelle Engebretson, a HAARP site coordinator. She is an employee of Advanced Power Technologies, Inc., a non-governmental agency which was running the operation during my Alaska visit. When you enter the HAARP facility, you don't get the appearance that there's anything governmentally secret going on here — no fingerprint checks, no background checks, no metal detector checks. Just drive up to the locked gate and ask for a visit.

High-frequency transmitter racks produce up to 3.6 million watts of power between 2.8 MHz to 10 MHz. Fire-hose-sized coax cables go out to the antenna network directly above the transmitters.

Huge racks of filters attenuate harmonics and spurious signals by at least 80 dB, and any spurious or harmonic signals above 45 MHz must be attenuated by at least 120 dB. Signals from 88 MHz to 200 MHz must be attenuated by 150 dB. The HAARP facility is keenly sensitive that the massive amount of transmitter power must not interfere with ongoing communications by other radio users on both HF, as well as harmonic products on VHF and UHF.

There are acres of phased-array antenna systems that conduct steerable radio beams to search the ionosphere. The antenna system is a rectangular Planar array of 180 elements, arranged in 15 columns by 12 rows, spacing between each element at 80 feet.

Each of the 48 elements are crossed dipole antennas, oriented north and south, east and west. There are separate crossed dipoles for the low-frequency 2.8 MHz to 8 MHz bands, and smaller dipoles for 7 MHz to 10 MHz.

The phased array allows an antenna pattern with a beam width of 9-30 degrees, beam steering of 30 degrees from vertical. Computers in the main building allow technicians to steer the transmitted signal anywhere in the sky. I asked whether or not they actually could create an aurora, and they said that there was absolutely *no way* man can do what only nature does best.

The skybound signals are partially absorbed at an altitude between 100 to 400 kilometers, depending on what frequency they are operating on. The intensity of the high-frequency signal in the ionosphere is less than three microwatts per centimeter squared. This is tens of thousands of times less than the sun's natural electromagnetic radiation reaching the earth, and hundreds of times less than even normal random variations in intensity of the sun's natural ultraviolet energy. In other words, when the HAARP facility is transmitting, reflections from the ionosphere won't be cooking your body or lighting up your living room.

During my visit to the HAARP facility, they were exploring the 80-kilometer level of the E-layer where Sporadic-E clouds may form. It was also indicated that a few months before my visit they were bouncing signals off of the ionosphere and could even detect abandoned mines throughout the state of Alaska. But again, I was assured this was more for meteorological and geological exploration, as opposed to any secret military over-the-horizon radar operation.

The visit to HAARP was an unbelievable experience of looking at the largest antenna system I have ever seen, aimed straight up!

six-meter and two-meter band openings that may last for hours over hundreds of miles of distance. But if you're in Alaska and the aurora is overhead, you might as well turn off the rig and go out and enjoy the sights.

On the 70 cm ham band, weak-signal operators using upper sideband and the horizontal polarization hang out at 432.100 MHz — the calling frequency. Again, everyone is horizontal so you wouldn't hear much with a vertical antenna. A simple horizontal loop for home use will pull in stations hundreds of miles away. Plenty of tropospheric ducting on 432.1 MHz and, like two meters, local meteor showers and meteor storms will raise a tremendous amount of activity that may last for several seconds during the meteor "burn." The recent Leonides meteor storm last November brought in some record-breaking contacts on the 440 MHz band using CW, data, and upper sideband.

Two-meter horizontal beam reached out over 400 miles during some mountain topping tropo event.

On the 23 cm, 1.2 GHz band, the weak-signal hangout is not at the bottom of the band, but rather near the top and 1296.1 MHz. This is the calling frequency, and again the mode is upper sideband and polarization is exclusively horizontal.

Even though you might have a multi-mode transceiver capable of listening to 1296.1 MHz USB, you won't hear squat on a vertical antenna because everyone else transmitting is horizontally polarized. But when you do hear stations talking on 1296.1 MHz, you will discover the weak-signal excitement of this band by listening to operators bouncing their signals off of nearby buildings, distant mountains, and even banking signals around small hills and into valleys. Ground reflections make operating 1.2 GHz fun and exciting for weak-signal work.

The 222 MHz band and the other ham bands above 1.2 GHz all require a transverter to bring these frequencies into the range of what you pick up with your HF + 6m +2m + 430 MHz mobile or base transceiver. There is a modest amount of activity of weak-signal work on the 222 MHz band, and microwave enthusiasts have gone to all-time highs to explore point-to-point weak-signal, upper-sideband, and CW operation at 10,000 MHz and 24,000 MHz. Imagine yakking across town on frequencies many bands higher than your microwave oven!

The weak-signal net control operators encourage everyone with one of those HF + 6m + 2m + 430 MHz transceivers to try to tune into their Sunday night and Monday night nets just above the calling frequencies. For a list of nets, as well as companion weak-signal groups throughout the United States, log onto the Western States Weak Signal Society web page at www.wswss.org, or write them at WSWSS, P.O. Box 5594, Sherman Oaks, CA 91413-5594.

Finally, licensed hams who work weak-signal operation regularly contribute many breakthroughs in exploring our airwaves and the ionosphere. My recent tour of Alaska saw ham operators at HIPAS beaming megawatts of energy into the ionosphere, developing their own mini-aurora. Same thing with the experiments at HAARP several hundreds of miles way — experiments from high frequency to microwaves to better understand all that the ionosphere is above us. There is usually a licensed ham operator behind every satellite and space experiment!

If you are a ham, listen in on VHF and UHF weak-signal operation and join in. NV

Brightly Using LEDs

Light-Emitting Diodes (LEDs) have been around since the mid-1960s. They have nearly replaced incandescent lights as indicators and in digital displays. They're even making inroads into AC line-operated lights. In particular, traffic stop-lights are now often made with LEDs. However, LEDs are not incandescent lamps. They have many qualities of their own, some quite surprising. This article will discuss the general characteristics of LEDs, practical applications, and some of the more unusual applications. The emphasis will be on nformation that may be fundamental, but is rarely discussed.

by Gerard Fonte

Basic Stuff

It's important to remember that an LED is a quantum device. That is, is works because of quantum characteristics of the particular atoms/molecules that make up the LED. This makes it much more efficient that an incandescent lamp. It also means that its operation is completely different. LEDs have a threshold voltage below which it simply won't operate. This forward voltage is directly dependent on the color of the LED (given the same semiconductor material). The redder the LED, the lower the forward voltage. Infra-red (IR) LEDs have the lowest forward voltage of about 1.2 volts. Blue LEDs have the highest at about 5.5 volts. But, there is variation depending on current and temperature.

LEDs have a maximum current rating and require current limiting or else they can be destroyed. The simplest method is to use a resistor to limit the current. In almost all cases, this is a perfectly good choice. However, certain LED driver chips have constant current circuits to provide improved performance. The brightness of LEDs is generally linear with the current; the greater the current, the brighter the display. However, there are a number of points to consider.

LED Brightness, Current, and Lifetime

First of all, LEDs do have a finite lifetime (generally defined as a 50% reduction in brightness). Typically, this is in excess of 100,000 hours or about 11 years of continuous duty. Obviously, this is generally not a great concern for hobbyists. However, this means that after five years, there will be a measurable reduction in brightness. This is a concern for items like clock displays and a serious concern for embedded LEDs in opto-isolators.

However, by reducing the current, the lifetime can be extended. LED lifetime is exponential with current. So, if the current is reduced by 50%, the lifetime can be increased by up to a factor of about 50 (while the brightness is reduced by about 50%). Conversely, it shows that running an LED at twice the rated current will reduce the lifetime from 100,000 hours to about 2,000 hours or about 83 days.

Obviously, everyone wants bright displays, so they push the current limits. Generally, this is not a good choice for several reasons. The first is subtle. The human eye is not all that good at discriminating brightness. A 50% reduction in brightness is not all that noticeable. (Try it. See for yourself. Use a 1K and a 2K series resistor.) The second reason is that it takes more power. This is always a concern for battery-operated devices. Additionally, more

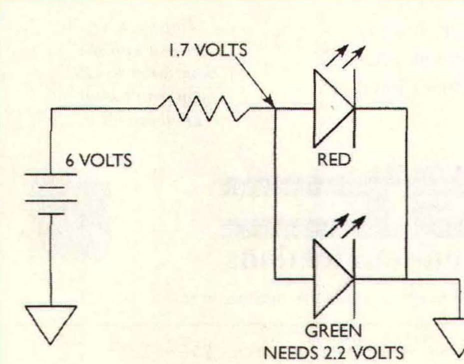


Figure 1. Using a single current limiting resistor doesn't work because the LED with the lowest forward voltage will pull the voltage down to that level.

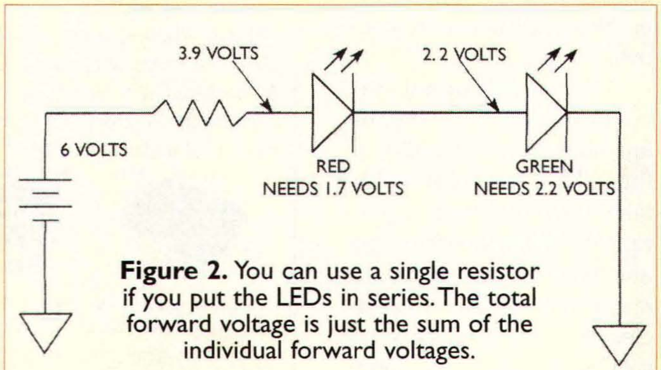


Figure 2. You can use a single resistor if you put the LEDs in series. The total forward voltage is just the sum of the individual forward voltages.

power means more radiated RF energy (from multiplexed drivers, etc.) during switching. This is called EMI (electromagnetic interference) and is not a good thing. Finally, if the current is even slightly above the rating, the lifetime is drastically reduced. In short, use only the current needed for an adequate brightness. Generally, I use 2-3 mA. (Lower LED current slows the response, so if you need the speed, run at high current.)

By the way, LED brightness is based on a model of the human eye (commonly called the CIE Curve). So, LEDs that have the same brightness rating, but different colors, will appear to be of equal brightness. I have seen some green LEDs advertised as being easier to see because the eye is much more sensitive to green than red. This is misleading. The mcd (milli-candela) rating is what determines apparent brightness.

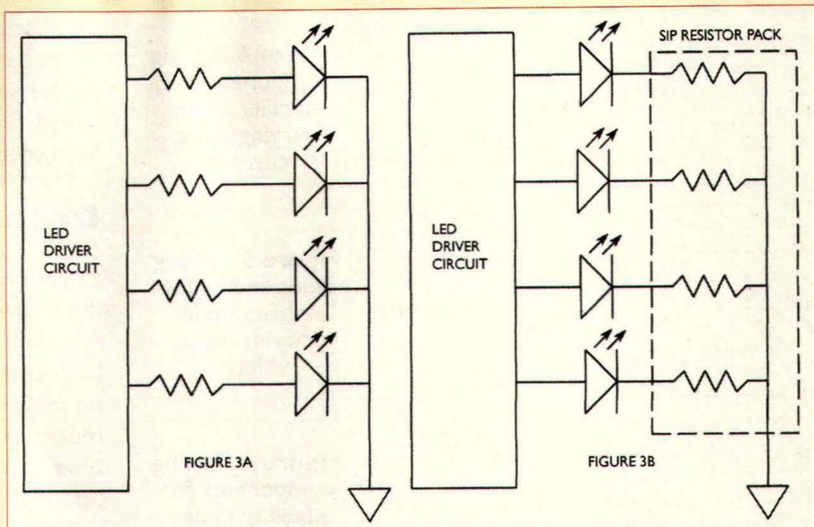


Figure 3. Although electrically identical, the subtle drawing change in Figure 3B allows the use of SIP resistor packs. This can significantly decrease production costs due by reducing labor and using less PCB area.

Duty Cycle and Multiplexed Displays

LEDs can be pulsed with a higher duty cycle than the rated current. Typically, pulses can be up to 10 times the rated current. Sometimes much more, if the LED is designed for that. Check the data sheet for details. The average current is the working factor. So, if the data sheet says that the DC current should be 10 mA maximum, then a 25% duty cycle pulse can be up to 40 mA. Of course, the pulses must be short enough to prevent heating and LED degradation. Typically, 10 mS is the maximum pulse length permissible. For really high currents, a 1 uS pulse and a 0.1% duty cycle may be needed. Again, check the data sheet.

The brightness of multiplexed/pulsed displays is generally brighter than expected when measuring the average power. This is because the human eye tends to respond to peak brightness.

Contrast Ratio

The ability to see a display clearly is more dependent on the contrast ratio than the actual brightness. Increasing the brightness of LEDs helps, but decreasing the background helps just as much. There are three easy ways to reduce the background light.

The first approach is to use a flat black background. This is good for discrete LEDs, but doesn't work that well for displays. This is because discrete LEDs are almost point sources while displays are clearly area sources, but the background color always is a factor.

The second method is a light-shield or hood. Instead of mounting the LED flush with a panel, recess it (say 1/4" to 1/2"). This blocks ambient light and increases the contrast ratio. The deeper the LED is recessed, the better. Of course, this cuts down on the viewing angle, but for portable instruments that need to work outdoors, this is a very good choice. The third technique is to place an optical filter in front of the LED. This allows the LED light to pass while blocking ambient light. This can be an extremely effective way to increase the visibility/readability of LEDs. Obviously, the filter color must match the LED color. Also, without getting into too much optical discussion, red LEDs work best with this approach. Ordinary red or green "plexiglass" will usually work perfectly well for red or green LEDs. If you need to be technical, the proper red is "2423" plexiglass and the green is "38168."

Circuit Tips

You can't parallel multiple LEDs with a single current limiting resistor (Figure 1). This is because the LED acts like a zener diode. It will try to pull the voltage down to its forward voltage (that's why the current must be limited). So, if you have a red and green LED in parallel with a single resistor, only the red one will light. This is because the voltage at the resistor/LED node will be about 1.7 volts (the red LED forward voltage) and the green LED needs about 2.2 volts to light. It may be possible to parallel "identical" LEDs with a single resistor, but this is generally not a good choice. This is because LEDs are not perfectly identical. Minor variations

TABLE 1. Comparison of stability versus current* for various components.

Current test See Figure 4	3.3V zener	5.1V zener	3 (series) 1N4148	Red LED #1	Red LED #2	Red Led #3	Green LED
1K series	2.5326	5.0526	2.2246	1.6184	1.6221	1.5810	2.0146
10K series	1.8507	4.9966	1.8502	1.5134	1.5248	1.4884	1.7923
100K series	1.3511	4.63**	1.4821	1.4063	1.4278	1.3808	1.6893
1 meg series	0.9751	3.72**	1.1395	1.2884	1.3215	1.2632	1.5842
10 meg series	0.6843	2.71**	0.7884	1.1665	1.2054	1.1436	1.4683
Voltage change	1.8393	2.3426	1.4362	0.4519	0.4167	0.4374	0.5463
% change	-72.6%	-46.0%	-64.6%	-27.9%	-25.7%	-27.7%	-27.1%

*Input was 10 volts. ** Last two digits were not stable.

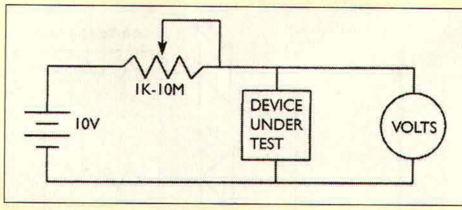


Figure 4. Testing components for stability under varying input current.

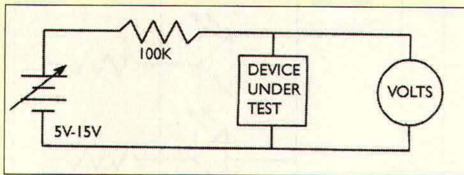


Figure 5. Testing components for stability under varying input voltage.

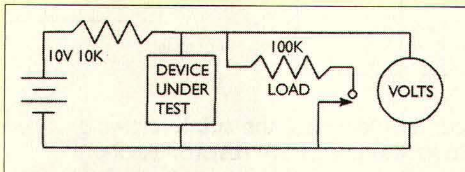


Figure 6. Testing components for stability under varying load.

can cause fairly significant differences in current between the LEDs. Generally, one LED will pull more current than the rest. This can cause current overload in that LED and shorten the life.

If you really want to save a resistor and light multiple LEDs, put the LEDs in series (Figure 2). This guarantees equal current through each LED. Of course, you need a higher voltage to light them (sum the forward voltages of the LEDs in series). But you can mix colors and the power efficiency is usually better.

The efficiency rises because there is less voltage wasted in the current limiting resistors. Obviously, 10 mA through one resistor uses less power than 10 mA through six resistors. Additionally, LED strings have forward voltages that are usually closer to the supply voltage. So less voltage is wasted. For example, in a five-volt system, each red LED (with a forward voltage of 2.2V) will waste 2.8 volts or 56% of the power, but six red LEDs in series need a forward voltage of 13.2 volts. If the supply is 15 volts, then only 12% is wasted.

Finally, a subtle practical point concerning series resistors. Figure 3A shows the generally-accepted method of placing the resistor between the driving voltage and the LED. I've seen it everywhere. In data books, construction magazines, military systems, professional schematics, etc. The resistor should be placed (as in Figure 3B) between the LED and ground (or VCC in current-sinking applications). Electrically, the circuits are identical, but Figure 3B allows the use of resistor packs with a common terminal.

Using these SIP (Single-Inline-Package) resistors can reduce production costs significantly. Dropping in a single component takes much less labor that forming and then trimming the leads of multiple resistors. It costs about 10-20 cents per resistor to form and trim leads in a production house. Add to that the cost of extra PCB (Printed Circuit Board) area needed for discrete resistors and it is clear that SIP resistors are very cost-effective. Additionally, SIP resistors are generally are better matched to each other than discrete resistors. And, SIP resistors are on the same thermal substrate, so temperature tracking is better. So, using SIP resistors improves reliability and performance, as well.

Opto-isolators

Most people tend to run the LEDs in opto-isolators at the maximum current in order to be sure it will work properly. This is generally not necessary or even desired. The LED current rating is a MAXIMUM rating. There is usually no minimum rating. I've run opto-isolators with a LED current of 800 uA without any problems. The reason is that most people overlook the key specification of opto-isolators — the Current Transfer Ratio (CTR).

The opto-isolator can be thought of as an amplifier. The CTR specifies the gain (or amount of amplification). For most "transistor-output" optos, the CTR is less than one (typical minimum values are 20% to 40% or a gain of 0.2 to 0.4). That is, the opto output can source or sink less current than that supplied to the LED. So, if you need 0.1 mA of output current for a logic gate, driving the LED with 1 mA will be fine.

However, "Darlington-output" optos have a CTR of greater that one (typical minimum values are 200% to 400% or a gain of two to four.) This means that the opto output will sink or source more than the current supplied to the LED. So, if you need 0.1 mA to drive your logic gate, then 0.1 mA into the LED will work. Note that the Darlington output optos are slower than plain transistor outputs. Darlingtons typically switch in 100s of uS, while transistor outputs switch in less than 5 uS. There are special high-speed optos available that switch in less than 50 nS. There is a big "gotcha" with the CTR. It has a huge variability, usually a factor of 10 or 1,000%. (Can you imagine a resistor with a 1,000% tolerance?) That is why designers always work with the minimum CTR. Normally, this isn't too important in most designs. It means that the output can source or sink more than expected. That's usually a good thing, but it must be considered.

Special Opto-isolators

There are opto-isolators with Triac and SCR outputs. With these, there is no CTR specified. Instead, they have a minimum LED current needed to switch on the SCR or Triac. Opto-isolators can be used with analog signals, but there are problems. The first is the CTR variability noted above. It can cause the analog output signal to be wildly

TABLE 2. Comparison of stability versus input voltage* for various components.

Voltage test See Figure 5	3.3V zener	5.1V zener	3 (series) 1N4148	Red LED #1	Red LED #2	Red Led #3	Green LED
5 volts	1.4506	4.8133	1.1568	1.4318	1.4492	1.3384	1.7144
15 volts	1.2091	3.9933	1.3597	1.3665	1.3898	1.4039	1.6496
Voltage change	0.2415	0.8200	0.2021	0.0653	0.0594	0.0655	0.0618
% change	-16.6%	-17.9%	-17.5%	-4.56%	-4.1%	-4.89%	-3.60%

* Current limiting resistor was 100K

variable from unit to unit. Some sort of adjustable gain control is usually needed. Additionally, the simple transistor output suffers from significant non-linearity (also known as distortion).

TABLE 3. Comparison of stability versus output load* for various components.

Load test	3.3V	5.1V	3 (series)	Red	Red	Red	Green
See Figure 6	zener	zener	1N4148	LED #1	LED #2	Led #3	LED
Voltage change	-6 mV	-5 mV	-4 mV	-1 mV	-1 mV	-1 mV	-1 mV

* 10K series resistor @ 10V. No load versus 100K load

However, there are some special optos designed for analog use. They can have a linearity of better than 1% and a CTR tolerance of less than 50%. There are also FET output optos which act as a light-controlled resistor. Finally, there are photovoltaic optos. These generate power at the output. Admittedly, it's pretty small (typically 10 uA at 8V with 10 mA LED input drive), but it may be enough to power your isolated micro-computer without batteries! Toshiba is one manufacturer of these.

Unusual Applications and Characteristics of LEDS

According to my antique (1985) General Instruments optoelectric data book, LEDs have a couple interesting characteristics. (All data books are important, old ones often have lots of application notes and specifications not included in new ones or on CD-ROMs.) The first is that LEDs vary their junction capacitance with voltage. This is not surprising. Nearly all semiconductors do. However, LED capacitance varies with the FORWARD voltage. Most other diodes vary with the REVERSE voltage. Secondly, the capacitance varies by a huge amount. Typically, at 0.0 volts, there is about 100 pF at the junction for an IR LED. As the forward voltage increases to about one volt, there is a roughly linear increase of capacitance to about 200 pF, but going from 1 volt to about 1.2 volts (where it emits IR light), the capacitance shoots up to 400 pF or more. Remember, this is just a general statement, any particular LED may be different.

Secondly, some LEDs have a nearly perfect linear response to heat. (Check the particular LED's data sheet for details.) In particular, the relative luminous intensity decreases with increasing temperature. Typically, at -35 degrees Celsius (-30 degrees F), the intensity is 155% of normal (at 0 degrees C or 32 degrees F). At 70 degrees C (158 degrees F), the intensity is about 60% of normal. Of course, you'll need a linear responding photodetector — like a photovoltaic cell — for measuring the relative intensity. This may or may not be a practical idea, but it eliminates all the non-linearities associated with thermistors.

Photodetectors

LEDs are also light detectors! Not only that, but they respond best to the color that they emit (or very close to it). So, for a few pennies, you can have a narrow-band color detector with a built-in filter. It's not too sensitive (the active area is tiny), but the price is right. They operate as a photovoltaic cell with the current increasing with the light intensity.

Forrest Mims III wrote the book on this. The original idea appeared in the May 1977 issue of Popular Electronics. The title of the article was "Using LEDs as Light Detectors." Somewhat more recently, in the May 1997 issue of Scientific American, The Amateur Scientist column by Shawn Carlson describes an extremely simple atmospheric haze sensor that Mims designed (but the pin-out for the 741 op-amp is wrong). You can get this and more information at www.concord.org/haze/.

Voltage Regulation and Reference

About 10 years ago, I needed a low-current voltage to bias an op-amp input. Simply using a resistor-divider to the power supply was not acceptable because any power supply noise and voltage variation went directly into the op-amp. The traditional method is to use a low-voltage zener or string of forward-biased signal-type diodes. But when I used a 3.3 volt zener at very low current (1 uA), the 3.3 volts I expected was only 0.68 volts. Three 1N4148 provided 0.79 volts instead of the expected 2.1 volts. So I performed some simple experiments with LEDs to see how they performed when compared to these standard methods.

The first test (Figure 4 and Table 1) was to see how the test device acted under a range of supply currents. I tested seven different diodes: a 3.3 volt zener, a 5.1 volt zener, three 1N4148 diodes in series, two different style red LEDs from the same manufacturer, a red LED from a different manufacturer, and a green LED. I varied the current from 10 mA to 1 uA for a range of 10,000 to 1.

As you can see, the LEDs have less than 20% to 30% the variation of the other diodes. More importantly, the variation between all three red LEDs was no more than about 5%. The second test (Figure 5 and Table 2) varied the input voltage from 5 to 15 volts with a 100K current limiting resistor. Again, the LEDs showed only 20% to 30% of the variation of the other diodes.

Lastly, I tested the diodes for variation under load (Figure 6 and table 3). The variation between no load and a 100K load was about 1 mV for the LEDs and 4-6 mV for the other diodes. (I used a Fluke 8800A, 5.5 digit voltmeter with 1,000 megohm DC input resistance for all the tests.)

I didn't test temperature variation. But I would expect good stability because of the quantum nature of the LED designs. This is because the forward voltage varies with color and the color changes only slightly with temperature. I also didn't do noise tests or stability-over-time tests. However, these tests are fairly straightforward. If anybody wants to do these, I'd like to hear your results.

Conclusion

LEDs are versatile components. Using them properly is important for reliable long-term performance. They also have some hidden capabilities that allow them to be used in a non-traditional manner. NV

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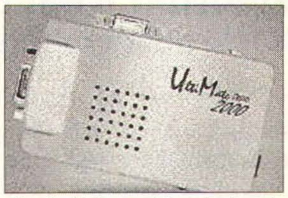

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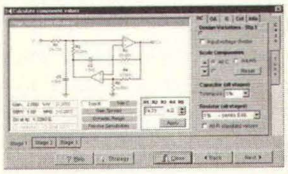

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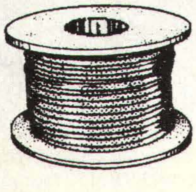

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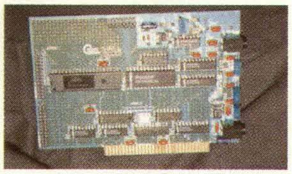

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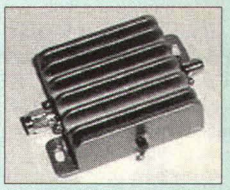

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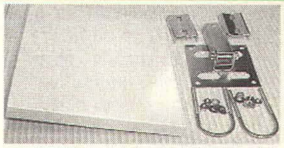

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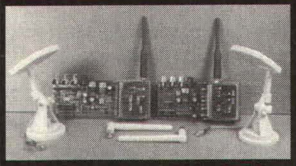

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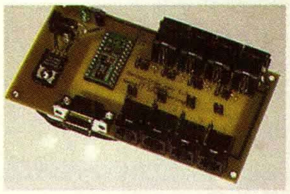

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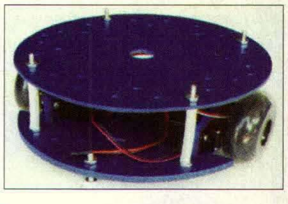

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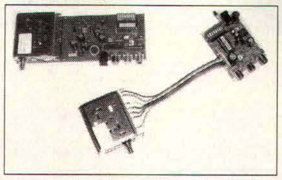

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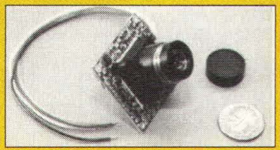

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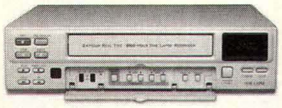

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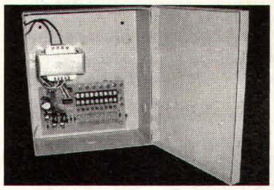

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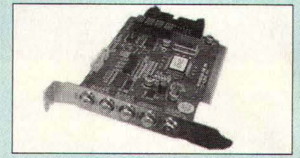

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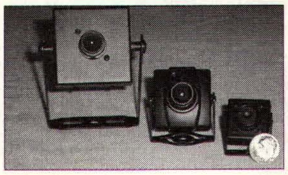

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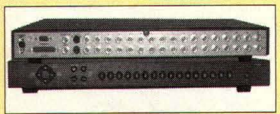
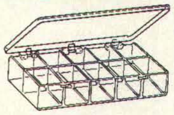
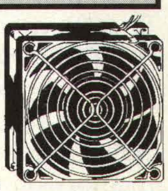
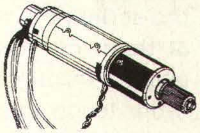








Understanding, Designing, and Constructing Robots & Robotic Systems

Amateur Robotics

Building an HC11 Serial Recorder

In this article, I will show you how to build a serial recorder. "What is a serial recorder?" you might be asking. Well, a serial recorder is something that records anything that comes through the serial port and stores it in memory for later viewing.

The serial recorder that you'll be building will be small, portable, and can record up to 32,767 characters (or more, if you get more memory on your HC11).

"What can this be used for?" might be another question. I'll answer this by giving an example. Say that you have a wall-following robot that is having trouble with one type of corner. Now an easy way to debug the program is to have the robot output the sensor values and other variable values to the serial port so that you can look at them on your computer screen using a terminal editor. However, in order to do this, you have to have your robot tethered to your computer. But with a serial recorder, you won't need to keep a cable hooked up because the robot or other device can carry the serial recorder.

All you do is plug the recorder into your computer, and run a terminal editor. Run the serial recorder (to do this put the HC11 into run mode) and press 'r' on your computer's keyboard. The HC11 serial recorder will start to record. Now whatever comes to the serial port will be stored in RAM.

Next, plug the recorder into your robot and run the robot's program. When finished, you simply plug the recorder back into your computer so that you can view whatever the robot said! Simple, isn't it? Read on to see how to build, use, and modify this serial recorder.

What You Need

All you need is an HC811E2 with 32Kb of RAM (can be battery-backed, but isn't required), and a micro switch (a switch with three pins: Common, NO, and NC). On the software side, you'll need WCC11, MHM and, of course, the C program for the serial recorder (all these files are available for free on my web site). You will also need PCBug11 (available at Karl Lunt's page) and a terminal editor (if you don't have a terminal editor, you can use the one in PCBug11 ... simply type 'term' while in PCBug11 and a terminal editor will pop up). The C file that you will need is at my web site and is called SCIRec.c. Also while you are at my web site, you will need to download SCI.c.

Now before going on, I just want to tell you that this is not a tutorial on how to use and build an HC11 system. This article assumes that you are familiar with the hardware and software that we're using.

Building the Recorder

Constructing the serial recorder is easy. First, get your HC11 system working. To do this, you can buy a board (see some links in the sidebar) or you can build your own board. Just make sure that you have the minimum requirements listed above (of course, you can have more that 32Kb external RAM).

Now construct the circuit as shown in Figure 1. This circuit uses the micro switch as a signal button that remains LOW when the button is not pressed, and HIGH when the button is pressed.

Simply connect the NO pin of the micro switch to +5V, the NC pin to GND, and the COMMON to PE0 on the HC11. That's all you have to do! If you want to, you can put the system in a plastic enclosure. Read on to see what the 'Note' button in Figure 1 will be used for ...

Modifying the Software

You may need to make a few modifications to the SCIRec.c C file. The only line that you might have to modify is the first line in the **main()** procedure. The first line is **point = 0x8000;**. This simply initializes the variable **point** to 0x8000. This variable is used to point to the next free memory address that can be used to record the serial port. You must point this to the start of your external RAM. If your RAM starts at address 0x8000, then leave the line alone. However, if your RAM starts at address 0x0000, then change the line to **point = 0x2000;**. Simply point the variable to the start of your RAM, however, don't go lower than 0x2000.

Compiling the Program

First, download and install all of the software I listed previously. Now run MHM and give it the following info:

Header Name: SCIRec
Stack Beginning: ff
Program address: f800
WCC11 v.1.0? (y/n): n

That will make the main header that is needed to compile SCIRec.c. Now run WCC11 and give it the following info:

File Name: SCIRec
Out File: SCIRec
Main Header SCIRec

That will compile SCIRec.c to SCIRec.asm. Now all that you need to do is assemble the file. To do that, run AS11 by typing in the following:

AS11 SCIRec.asm

That's it! If you do a directory, then you should see the file SCIRec.s19. If the file doesn't exist, then you must have missed a step above ... simply try it again. To download the program, use PCBug11 or any other downloader that you normally use and download SCIRec.s19 to the HC11's internal EEPROM.

Testing the Program

Just to make sure everything is working, let's run a quick test. First, run a terminal editor on your computer, and then plug the serial recorder into your COM port. Now run the program by switching the HC11 into run mode. You should see the message 'SCI Recorder is Running' show up on your computer's screen. If the message didn't show, then the program isn't running (make sure you compiled the program as described above). Now, if the message did show up, then do the following (I'll explain it all in a little bit ... just trust me for now):

r0123456789 0123456789

Then press RESET on the HC11. The same message ('SCI Recorder is Running') should show up. Now type 'l.'

You should see a '0' show up. Now press any key and a '1' should show up. Again, if you press any key a '2' should pop up. If you continue doing this the whole message you recorded above (0123456789

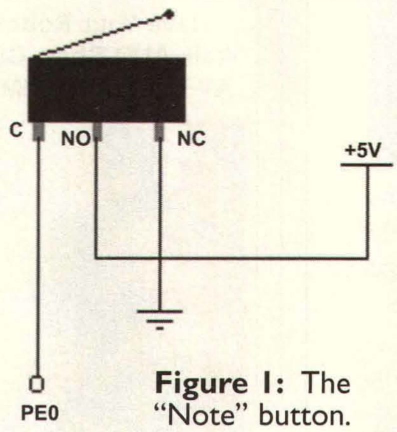


Figure 1: The "Note" button.

0123456789) should show up. When the serial recorder reaches the last '9' (this is the end of the recording), the message 'SCI Recorder is Running" should show up again. If all this happened, then everything is working so far!

Recording Messages

Okay, now let's take a closer look at how to use the recorder. For this first part, you should simply plug the recorder into your computer's serial port and run a terminal editor.

After running a terminal editor, run the HC11's program. Again, you should see the intro message. Press 'r' on your computer's keyboard. Now, if you were going to record a robot's serial port or other serial port, this is where you would unplug the recorder from the computer and plug it into the other device, however, just to show you how the recorder works, keep the recorder plugged into the computer. Now type in a simple message that you want to record (for this example, type in 'Hello World!'). When you're finished, press RESET. This is what you would do when you are finished recording a serial port. Now, to play back the message, press 'l' for list and press a key on your computer's keyboard whenever you want to see the next character. Go through all the characters until the intro message is displayed again.

More Features

Now suppose you want to see more than one character at a time. Say, for example, that you want to see a word at a time. To do this, first reset the HC11. After the intro message is displayed, press 'w,' and then 'l.' You will notice that 'Hello' is displayed. Now press any key on your computer's keyboard (just like you did before). Now you should see the word 'World!' displayed.

The recorder now shows words instead of characters because you typed in 'w' before 'l.' There are several commands that the serial recorder understands. Here is a list of them all:

r : Begin recording.

l : List the recording (runs the **List()** procedure [**List()** is defined in **SCIRec.c**]).

w : Tells **List()** to print a word at a time.

c : Tells **List()** to print a character at a time (this is the default option).

p : Tells **List()** to print a few characters at a time.

n : Find next note (explained later).

So basically, if you want to have the recorder print a few characters at a time, type 'p' and then 'l.'

The 'w' command will read a word at a time. Using the 'w' command tells the recorder to print out a string of characters until a 0x20 is reached (0x20 is the ASCII character for SPACE). After a word is printed, the serial recorder will wait for an input from the user. The user inputs data to the recorder via a computer running a terminal editor. (Anytime I mention that an input is needed to be given to the HC11, I mean that the input should be given via a terminal editor running on a computer. There is only one input that is not input via the serial port and that is the microswitch 'Note' button.)

The 'c' command is the default option. Using this command will tell the recorder to print out a character and then wait for an input from the user. Once an input is received, the next character is printed.

The 'p' command tells the HC11 serial recorder to print out a certain number of characters before waiting. When you first download **SCIRec.c** from my web site, the 'p' command is set to print 20 characters at a time, however, you can easily change this number. First edit **SCIRec.c** and change the line that says:

```
pauseMax = 20;
```

You will see this line right under the start of the **main()** procedure. Change the **20** in the line to the number of characters that you want printed (changing it to 50 will have the 'p' command print 50 characters before waiting for an input). After you modify the software, you will need to recompile.

Those are all the basic modes for the 'l' command, however, there is one more ... the 'n' command.

Taking Notes

There are advantages to using this serial recorder instead of a wireless link. For example, the support for taking notes.

A note is simply an event where you want to place special attention. Say that your wall-following robot is having trouble at a certain spot ... take a note. That way, you can see what the robot was saying while there was trouble.

To take a note while recording (after typing 'r'), press the microswitch button that you wired to the HC11. This button is the note button. Pressing it will cause the HC11 to store an 0xFF before the character. 0xFF is a blank to a terminal editor, however, you can have the HC11 scan the memory for those 0xFFs to jump directly to that area.

To have the serial recorder find a note after recording (to stop recording press RESET on the HC11), press 'n.' That will tell the HC11 to find the nearest note (in this case, the first one). Press 'n' again to find the second note, and so on. Now after finding the note you want, select your display mode ('c,' 'w,' or 'p') and press 'l' to list. However, now instead of starting at the beginning of the recorded message, the HC11 will display the recorded message after the note.

One Quick Example

Here's an example of how to use the serial recorder. First, run a terminal editor and plug the recorder into your computer's COM port. Run the recorder. You should see the intro message printed.

Now type 'r' to begin recording. All you need to do now is unplug the recorder from the computer and plug it into the serial port that you want to record. During recording, you can press the note button at any time to take a note of a certain spot. When you're finished recording, unplug the recorder and plug it back into your computer (the computer should still be running a terminal editor).

Now press RESET on the recorder. The intro message should once againpop up. Select the list mode (explained earlier in this article) and press 'l.' You will see the message printed out. When the message stops printing (like at the end of a word if you're in 'w' mode, or at the end of a character if you're in 'c' mode), then simply press any key on your computer's keyboard to resume displaying the message.

When the message is finished, the serial recorder will reset itself and you will see the intro message again. Now you can record a new message or list the message again. Also, at any time, you can press RESET on the recorder to input a new list command or record another message (if you record another message, the old one will be deleted).

Conclusion

I find that this serial recorder has saved me tons of debugging time. I'm sure it will also be able to help you. Feel free to change and hack through the serial recorder. I hope this article has been helpful and if you ever need help, just contact me through my webpage. Good luck with your project, and have fun! **NV**

LINKS

www.frontiernet.net/˜wkrawec/page3.html. My page. You can download WCC11, MHM, and SCIRec.c here.

www.seanet.com/˜karllunt. Karl Lunt's page. He knows a lot about the HC11, and you can also download PCBug11 here.

www.technologicalarts.com. Technological Arts sell several HC11 boards that can be used for this serial recorder.

www.mrrobot.com. Mr. Robot also sells several HC11 systems that can be used with this project.

www.rdrop.com/users/marvin/. Marvin Green sells the BotBoards. The BotBoard2 can be used to build the serial recorder.

Just a quick note: Those three links above are only a few of the many companies that sell HC11s. Look around on the web, I'm sure you can find one that you like.

Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Stamp Applications

PBASIC Gets A Make-Over

The phrase "something old, something new ... " is usually associated with wedding ceremonies, but is a perfect description of the BASIC Stamp and the Version 2.0 editor combination: The same "old" (I write that lovingly) BASIC Stamp — that has been working reliably for years — combined with a brand new editor that includes some fantastic updates to the PBASIC programming language.

I've been programming BASIC Stamps for almost nine years now and I can say without hesitation that the last couple of months have been the most fun. The new PBASIC editor actually makes the BASIC Stamp seem like a brand new microcontroller. Have you ever owned an old car that you loved so much that you had it painted instead of trading it in and suddenly, that old car seems like it was brand new? That's how the BASIC Stamp feels now — even the stock BS2— using the new editor. It genuinely feels like a brand-new machine. The best part is that this "new" feeling comes absolutely free!

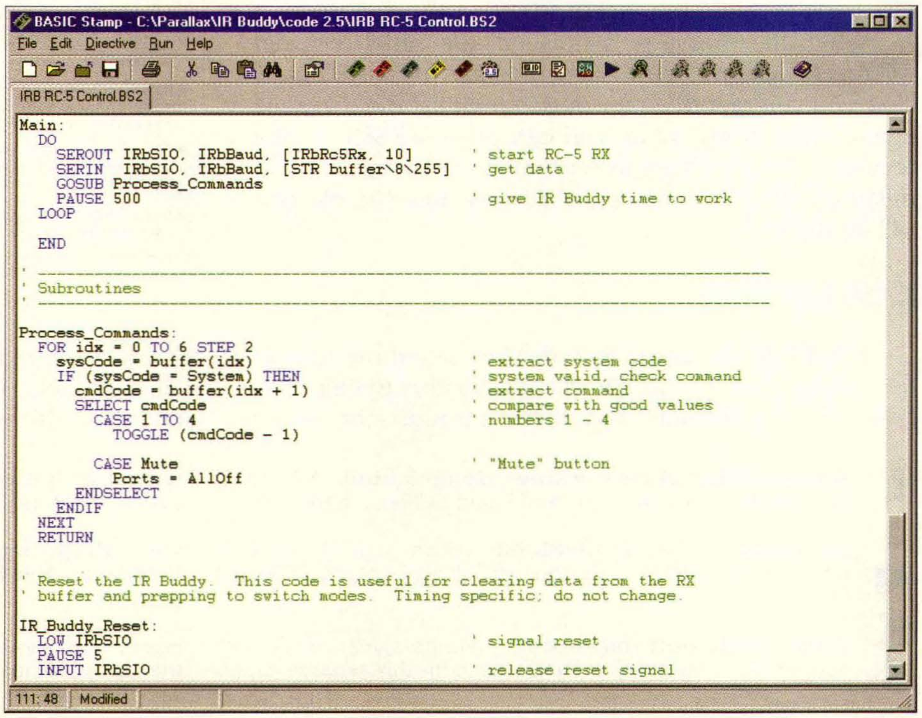
So what, exactly, is new? In a nutshell, PBASIC has been "normalized" to include BASIC language syntax that most programmers consider standard. Things like **IF-THEN-ELSE**, **DO-LOOP**, and **SELECT-CASE**. The editor also includes color syntax highlighting that makes editing and debugging PBASIC programs a lot easier.

What Took You Guys So Long?

Now, critics will [rightfully] ask: "What took you guys so long? People have been doing this stuff for years ..." The criticism is not entirely unfair and there is no excuse for the delay; especially since customers have asked for these updates for quite some time. There is a valid reason, though.

Keep in mind that the BASIC Stamp was developed in the early 90s, back when the Intel '386 was the king of the microprocessor hill and PC speeds were measured in the low tens of MegaHertz. Chip Gracey — the BASIC Stamp designer — decided to write the original development tools using Intel 80x86 assembly-language to get the best performance on the machines of the time.

Even though he's considered one of the world's best assembly-language programmers, Chip will freely admit that the BS2 tokenizer (the code that converts PBASIC to the EEPROM image that is actually downloaded into the Stamp) was a



significant challenge — and a good reason why there are a few BASIC Stamp kind-of-work-alike products, but no actual third-party BASIC Stamp clone that works with the Parallax editor/compiler. You see, the Parallax tokenizer is more than a compiler; it actually compresses the tokens so that the 2K EEPROM on the BS2 can hold more than 2K worth of instructions and data. It's more than a bit tricky, to say the least.

Once it was all working, you can imagine that no one was anxious to tear into the tokenizer for more than updates as were required to support new BASIC Stamps. When Parallax decided to create tools for Windows, the assembly-language tokenizer was simply linked to the Windows editor, which worked because Windows and the tokenizer were written for Intel platforms. Ultimately, however, the popularity of non-WIntel operating systems and platfoms and many BASIC Stamp users' desires to have native tools for these platforms won out.

So, a little over a year ago, Jeff Martin of Parallax began the arduous process of converting the assembly-language tokenizer to C (for portability to virtually any OS). Testing the new tokenizer took nearly as long as writing it. And testing is something that Parallax is very cautious about, especially when it comes to anything that affects the millions of BASIC Stamps that have already been sold. This process took quite a while because literally thousands of BASIC Stamp programs were compiled and the output was compared with the existing assembly-language tokenizer to ensure a perfect byte-for-byte match. Once the new tokenizer was fully tested and approved, it was folded into the editor and has been there since version 1.32. The tokenizer is also available — pre-compiled only — for Windows, Mac, and Linux developers.

And now for the good stuff. With the tokenizer much easier to update, making changes to it and the way it handles PBASIC language parsing becomes simpler to implement and to test. And that's what gets us to where we are today. Based on customer requests and using other versions of BASIC as models, PBASIC has been updated. The nice thing is that if you do nothing with your old code, it will compile in the new editor as-is. If you choose to use the new language features, you just tell the editor that's what you're doing and away you go.

PBASIC 2.5

Since the language update affects only the BS2 family, it is being labeled PBASIC 2.5. To tell the editor that you're writing using this syntax, you'll add a compiler switch at the beginning of your code:

```
' {$PBASIC 2.5}
```

This is similar in format to the $Stamp directive used to identify your target hardware and must be on its own line. There's also a new toolbar button that will drop this switch in for you.

Probably the most requested update to PBASIC has been the inclusion of **IF-THEN-ELSE**. In classic PBASIC, the **IF-THEN** construct is identical to the assembly code that it calls and takes this syntax:

```
IF (condition) THEN label
```

This syntax is still valid and does work under PBASIC 2.5. But what BASIC Stamp customers have long asked for and now they can use is this:

```
IF (condition) THEN
 ' statement(s)
ELSE
 ' statement(s)
ENDIF
```

For those with a background in other versions of BASIC, this looks quite normal — with the possible exception of the **ENDIF** keyword. **ENDIF** was selected over "END IF" (as in Visual BASIC) to simplify the tokenizer parser and keep things efficient.

There is a bit of short-cutting the programmer can do, depending on the complexity of your code. For example:

```
IF (condition) THEN
 GOSUB label
ENDIF
```

can be simplified to:

```
IF (condition) THEN GOSUB label
```

While not frequently used, PBASIC does allow multiple statements on the same line. I don't generally advocate using more than one statement per line, the example above being an exception that I do use in my own code. If you have just one statement per block, you can put **IF-THEN-ELSE** on a single line like this:

```
IF (condition) THEN statement ELSE statement
```

Note that **ENDIF** is not used when **IF-THEN-ELSE** is on a single line. Finally, while not recommended, you can put multiple statements per block on one line by separating the statements with colons.

```
IF (condition) THEN statement1 : statement2 ELSE statement
```

I tend not to use this syntax style because it leads to long lines that can become error-prone when editing.

And while we're on the subject of long lines, another frequent request by BASIC Stamp users is the ability to split a single long line across two or more shorter lines. This is now possible — so long as you've got a list on the line that is separated by commas. If this is the case, you can separate the long line at the comma character. Here's an example:

```
BRANCH value, [Target1, Target2, Target3,
      Target4, Target5, Target6]
```

Breaking lines at commas also works with **DEBUG, SERIN, SEROUT, LOOKUP, LOOKDOWN** – anywhere you have a comma-separated list of items.

Back to language updates. I never asked Chip, but I'm pretty sure that **BRANCH** was inspired by the old GWBASIC/BASICA syntax:

```
ON value GOTO Target1, Target2, Target3, ...
```

For those of you that have used those "older" PC versions of BASIC, you'll also remember this:

```
ON value GOSUB Sub1, Sub2, Sub3, ...
```

Good news: Both now exist in PBASIC. The latter is particularly useful in the style that I like to write programs for robotics. My preference is to have a main control loop that calls small routines and can change the order that these routines run based on current conditions (sensor input, etc.). In the past I used **BRANCH**, but this meant that all of my code blocks had to have a **GOTO** back to a single location; a location that could change, which meant multiple edits. By changing **BRANCH** to **ON** value **GOSUB**, this is no longer a requirement as the **RETURN** at the end of my subroutines will handle getting them back to the right place and also makes them call-able from other locations in the program.

This is really good stuff. Let's keep going!

Another new language feature for PBASIC is **DO-LOOP**. Its general form is defined a couple of ways. Here's the first:

```
DO
 ' statement(s)
LOOP
```

This form is an infinite loop that will run until a **GOTO** or **EXIT** (new keyword) breaks us out.

```
DO
 idx = idx + 1
 IF (idx >= 10) THEN EXIT
LOOP
```

Note that **EXIT** will cause the program to jump to the line that follows **LOOP**. While valid, another – arguably better – way to write this loop is like this:

```
DO
 idx = idx + 1
LOOP UNTIL (idx >= 10)
```

If we look at the first two examples, the value of idx is incremented before testing and the loop code runs at least once. We can check the limit before running the loop code if we rewrite it like this:

```
DO WHILE (idx <= 10)
 idx = idx + 1
LOOP
```

Another thing that I should point out is that **UNTIL** and **WHILE** can generally be interchanged, though most programmers will use them as I've demonstrated above.

The last major language update is the addition of **SELECT-CASE**. In PBASIC, its implementation is like this:

```
SELECT expression
 CASE condition(s)
  ' statement(s)

 CASE condition(s)
  ' statement(s)

 CASE ELSE
  ' statement(s)
ENDSELECT
```

The expression portion is a variable, constant, or expression. The condition part of each **CASE** statement is very flexible, as in other versions of BASIC — but with some of the additional flexibility that we're accustomed to in Parallax BASIC.

Here's how the **CASE** syntax works:

```
CASE conditional_op expression
```

Where conditional_op can be = (implied), <>, <, >, >=, or <=. Multiple conditions within the same **CASE** can be separated by commas. If, for example, you wanted to run a CASE block based on a value being less than five or greater than 10, the syntax would look like this:

```
CASE <5, >10
```

Here's another way to implement **CASE**:

```
CASE value1 TO value2
```

In this use, the valid range is from value1 to value2, inclusive. Let's take a look at a bit of actual working code. This subroutine is lifted from an update of the device controller example using the Parallax IR Buddy. In this code, one of four outputs will be toggled if the corresponding numeric key is pressed on a compatible TV remote. If the Mute button is pressed, all outputs are turned off.

```
Process_Commands:
 FOR idx = 0 TO 6 STEP 2
  sysCode = buffer(idx)
  IF (sysCode = System) THEN
   cmdCode = buffer(idx + 1)
   SELECT cmdCode
    CASE 1 TO 4
     TOGGLE (cmdCode - 1)

    CASE Mute
     Ports = AllOff
   ENDSELECT
  ENDIF
 NEXT
 RETURN
```

Notice the use of **CASE** 1 **TO** 4 for the decoding of numeric keys from the remote and the implied equality when handling the Mute button value.

For those that come from a C or Java background, you know that in those languages the statements in **CASE** block fall through to the next **CASE** block unless the keyword **break** is encountered. In BASIC, the code under an executed **CASE** block jumps to after **ENDSELECT**. In PBASIC 2.5, we have the option to make it drop through to the next **CASE** block for condition testing, if we choose.

In order to make **CASE** code drop through to the next **CASE** block, we will change the subsequent **CASE** to **TCASE** (through CASE). After execution of the statements within the **TCASE** block, the program jumps to after **ENDSELECT**, unless followed by another **TCASE**.

A New PBASIC, A New Type

A big part of the BASIC Stamp's success is due to the variable type flexibility: Bit, Nibble, Byte, and Word — I'm often wishing the PC versions of BASIC (and other languages) allowed bit and nibble variables. With the new language comes a new type definition: **PIN**. The reason for the **PIN** type is that some elements of PBASIC expect an I/O pin value in the form of a constant, while other elements require a variable (i.e., In0 or Out13). By using **PIN** instead of **CON**, we no longer have to concern ourselves with syntax; the editor adjusts automatically.

Let's look at an example from the IR Buddy. In classic PBASIC, the serial pin was defined like this:

```
IRbSIO  CON   15
```

... which works fine for **SEROUT** and **SERIN**. But one of the features of the IR Buddy is that it will indicate that it's busy transmitting by pulling the serial line low. In order to monitor the serial line, we had to write code in this style to use the previously-defined pin constant:

```
TX_Wait:
 IF (Ins.LowBit(IRbSIO) = 0) THEN TX_Wait
```

Works, but is a bit clunky. In PBASIC 2.5, we change the serial pin definition to:

```
IRbSIO  PIN 15
```

... which has no affect on **SEROUT** and **SERIN**, yet greatly simplifies the busy check.

```
TX_Wait:
 DO WHILE (IRbSIO = 0) : LOOP
```

The editor is intelligent in its analysis and evaluates the code as:

```
DO WHILE (In15 = 0) : LOOP
```

If, on the other hand, we had written:

```
IRbSIO = 1
```

The editor would evaluate this statement as:

```
Out15 = 1
```

In the end, the **PIN** type lets us think about I/O pins as I/O pins and the editor correctly handles the syntax details. As with the other improvements, it just makes PBASIC easier and, dare I say, more joyful to use.

Okay, I'm almost out of space, but I want to share just one more update. This will really be welcomed by those who use the BASIC Stamp's EEPROM as data storage or table space. **WRITE** and **READ** have now been updated to work with 16-bit variables. To make this happen, you put that modifier Word in the code. Like this:

```
WRITE address, Word value
READ address, Word value
```

The approach used is Little-Endian; the low-byte of value is stored at or read from address and the high-byte at or from address+1. Keep this in mind when writing data storage programs that expect 16-bit values in consecutive locations. If you're storing or reading Words, you'll need to increment your EEPROM address pointer by two for your next access. If you leave out the Word modifier, WRITE and READ will work with Bytes as in classic PBASIC.

The new editor with PBASIC 2.5 is scheduled for release toward the middle of this month, so be sure to check the [also new and improved] Parallax web site for details. Let me stress one more time that this is just an editor upgrade — you do NOT need to return your BASIC Stamps for reprogramming. How often does that happen ... a new BASIC Stamp without updating or buying a new BASIC Stamp? Now that's cool.

Happy New Year! And until next time, Happy Stamping. **NV**

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The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Project versus Product

Introduction

This is the first in a series of columns that looks at the business perspective of electronics. This is about the things learned from experience, rather than from a textbook. This is about practical electronic design direct from the trenches. Hence the title. The idea is to show how to design better with real-world examples and from lessons learned the hard way.

Project vs. Product

As an independent product designer, I am regularly approached by people with an idea that they want to produce. Typically, they have a "working prototype." All that is needed, they think, is a little tweaking to really make it great. Unfortunately, most of the time, their "working prototype" can never be tweaked into a product. Rather, the whole approach must be discarded and the idea completely redesigned. This is because their "working prototype" is a project rather than a product. Please note: Their idea may be great, it's the implementation that I am discussing.

The fundamental misconception is that a piece of working hardware is a product. It isn't. A product is something that is reliable, manufacturable, profitable, and saleable. A project is something that is self-made for enjoyment, education, or to prove a concept. Again note: A project is certainly a probable step in creating a product. But, it is not a product.

Don't Force-Fit the Design

The first step in the design of a product is the most important. This is the technique you choose to design with. Analog? Digital? ASIC (Application Specific Integrated Circuit)? Software intensive? Hardware intensive? CMOS? Bipolar? Do you know the trade-offs between these techniques?

Often I hear: "I did it that way because that's the only way I knew how." This is a fine answer for a project, but not for a product. Since there are always many ways to approach a problem, that "only way" is not likely to be the best way. The result is a force-fit design.

For example ... One client manufactured a product that measured the temperature of animals internally. The client chose an analog approach. He used a thermistor coupled to an oscillator as a temperature-to-frequency converter. Then he used this signal to create constant length pulses which he rectified and then filtered to get a DC signal proportional to the temperature, and scaled that to interface with his control system. Clearly, this approach will work. Also, clearly, it is awkward.

Not surprisingly, the client had problems with repeatability between units. So he added trimmers for adjustment. Since the battery voltage affected the oscillator, he added a voltage regulator. He wanted this circuit to run for 60 days on a small battery. But, continuous operation drained the batteries in five days. So, he added a timer-switch that turned off the circuit for 90% of the time. As you can see, he forced the design approach and it became overly complex and unreliable. How would you approach this design? Why is your approach better?

Read and Learn, Forever

Naturally, no one can know everything. But, it is very important to be familiar with many techniques. This requires you to read, read, read. Read trade journals, magazines, application notes, databooks, advertisements, and go to manufacturers' seminars and trade shows. Before you start drawing the schematic, stop and consider the *best* approach. The easiest, most familiar way may not be the best.

And don't be afraid to learn. That's something engineers are supposed to be good at. A smart engineer's education never stops. Besides, learning a new technique means that you have a good reason to get that new software simulator, hardware development system, or test instrument that you've wanted. Also, form a network of designers. In this way you can help each other out. Your strengths will benefit everyone in the group. Conversely, their strengths can help you choose the best approach and design a better product.

Design Factors

The next step is refining the design approach for your product. Is surface mount appropriate? Is reliability more important than cost? Is size a factor? How easy will it be to manufacture? Is the production quantity going to be large or small? These are the "design-for" factors and each is the subject of many books (*Design for Quality, Design for Production, Design for Testing,* etc.).

Don't blindly choose the hottest or newest technique. Choose the best technique. It may be fun to try out the latest multilayer PCB design software and create a six-layer board that's state-of-the-art. But is that level of technology necessary?

Remember, a product costs money to design, produce, and support. The most cost-effective approach is rarely the most technologically advanced. The reason for that statement is because most products are not that technologically advanced. Use the most appropriate technology for the product.

For example, a client needed a simple transmitter to signal a relay to close. He had heard about spread-spectrum transmitters and wanted to design with that approach. It was new and sounded very sexy for his product. He thought it would be a nice selling point. In those areas, he was probably correct. However, his technical requirements — very low power, very small size, simple receiver, low cost, and no external transmitter antenna — made the spread-spectrum approach impractical. What approach would you use? Why? How would you convince your customer/boss that your approach was better without upsetting him/her? People skills are important in design, too.

Reliability

A big difference between a project and a product is reliability. A product *must* be reliable (yes, even software!). It's okay if you have to make continual adjustments on your home-made receiver. But, a customer expects a product to work the first time and every time. Would you settle for a radio that kept drifting off-station every five minutes?

Give your product to others and *listen* to all of their comments (this is called "marketing"). Look closely and fix the weak points in your design. You can be sure that these weak points will cause problems. Fix them before you start production. *They will not go away by themselves!* It's always easier to re-design a product before sales have been made.

Some people are in a hurry to get a product out, so it's sold with known defects. The idea is to get some money and then re-design the product. This is both short-sighted and of questionable ethics. Selling unreliable products will give you a bad reputation. So, even if you fix your product, you have lost customers. Lost customers are not likely to buy anything from you again. Your customers give you money. Cherish them.

Know Your Market

Probably the hardest part of any product design is the marketing. This is *not* advertising or selling. Marketing is listening to the customer base. Advertising is talking to the customer base. A product should be in your area of expertise. Partly because you can design it well. But mostly, because you will have an understanding of what your customers want. That is, you know the market. A product must have a market. A project has no market.

For example, it would make perfect sense for an engineer to develop a new type of test instrument that fellow engineers would like to use and buy. That person knows what is currently available and has some idea of how the new product compares. This is vitally important information. This tells you how the market will react to your product. That is, if there is a demand for your product.

It makes less sense for an engineer to develop a new eating utensil. The combination spoon-fork may seem like a great idea. But how much do you know about other eating utensils? Are there other "sporks" available? Have they been tried before? If so, why aren't they generally available? How much effort are you going to spend learning about flatware? Probably not much. Because, if you were that interested, you'd probably be working for a company that designed them. Without a solid understanding of the market (which does take a lot of effort), it's virtually impossible to sell a product profitably.

Pricing Your Product

A project is rarely cost-effective. Most often there is an inordinate amount of labor that must be expended. Most often, this labor cost immediately makes the "product" impossible to manufacture profitably. I have found that few newcomers to business have a feel for how much it costs to manufacture a product.

Briefly, you must plan on $25.00 to $35.00 per hour for labor. This is what is called a "loaded labor cost." It includes salary, benefits, taxes, rent, equipment, and everything else. So, if it takes two hours to assemble your product, with $35.00 worth of parts (don't forget the costs of the PCB), the basic production costs will be about $100.00. This makes your selling price at least $200.00. This covers your profit, taxes, advertisements, development costs, and so on. Sometimes a person will build and sell the product as an individual. In this way, the costs are kept low. However, this creates a problem. Suppose, in the above example, you personally assembled the product and paid yourself $10.00/hr. Since you have your own equipment, home, etc., your overhead is low. So you manufacture your product for $55.00 and then sell it for $80.00. This seems good. You are getting $25.00 profit per unit.

Now suppose you get an order for 1,000 units. Sounds great! A $25,000.00 profit! But, in reality, this is a disaster! One thousand units will take 2,000 hours to assemble. This is 50 weeks at 40 hours per week. No one will wait a year for delivery. So, you need to get outside help. This will force the cost of your product up beyond the price you are selling them for, to about $100.00. You will lose $20.00 per unit, or $20,000.00!

This is because your "product" was a "project." You were spending your time at an unreasonable cost. With a project, time spent has little meaning. With a product, the labor time is usually the greatest factor in pricing. This is why many products are assembled overseas. The labor costs can be reduced substantially. (But the quantities and lead times are large.)

Product Design Philosophy

A successful product is not simply a piece of hardware or software. Rather, it is a combination of many factors and considerations that must be addressed from the start. With a project, these factors are not important. So you can now see why it's often difficult to convert a project to a product. I follow the KISS (Keep It Simple, Stupid) approach for all my designs. This results in reliable, cost-effective products. I will often use a single, more expensive, part to replace a number of lesser expensive parts. This reduces labor costs which usually more than offsets the increased parts cost. Additionally, fewer parts means a simpler, smaller PCB which further reduces cost and increases reliability.

A few words concerning PCB design. First, there is rarely a true need for more than a two-layer board (standard double-sided board). In fact, virtually all analog boards can be single-sided (but I often use the second side as a ground plane for improved performance).

Secondly, I have yet to find a PCB autorouter that is worth using. This is because the PCB layout is a critical factor in product performance and reliability. The low-end routers don't know the difference between a high-current output trace and a sensitive sensor input trace. Naturally, this causes degraded performance and some strange and very difficult-to-find failures.

Finally, these routers tend to use small trace widths because it's easier to route thin lines. This further reduces reliability because thin traces (and spaces) are more easily damaged and are harder to manufacture. (I typically use 0.020 inch traces and 0.015 inch spaces.)

Conclusion

Product development is fun and interesting. But, it requires a balance between many factors. So, it's not as simple as it first appears. However, as in many areas, common sense and attention to detail are the most important requirements. This has been a very brief look at what a product is. In future columns, we'll look at other aspects of "engineering as a business." Hopefully, it will help you avoid the errors that others have made. **NV**

by Stanley York

Exploring and Experimenting With Lasers and Their Properties

Laser Insight

Building a Battery-operated Optical Pulse Detector

Last month, we took a quick look at some different photosensors and their relative usefulness when applied to the detection of high-speed optical pulses. Some of the disadvantages with light-dependent resistors (LDRs) and photovoltaic-type semiconductor sensors were pointed out. The photoconductive-type diodes are generally accepted as being probably the best (in terms of speed, anyway) among the laser industry. Photoconductive diodes can be made very small, and the size really determines how fast the diode can respond to a given optical stimulus. A small diode junction means lower junction capacitance and consequently a faster charge (or discharge) rate.

Usually, anyone in the laser industry would use an optical energy meter to measure the actual energy in the laser beam. This device most often uses a thermopile and blackbody absorber to convert the light energy into heat, and then process the information from the thermopile to display the energy in Joules (after James Prescott Joule, the British scientist and inventor who did much to quantify the relationship between work, energy, and heat). Unfortunately, the laser power meter is another instrument that is rather specialized, and thus quite expensive. If you're lucky, you may come across one at Laser Resale (Sudbury, MA). Their web site is **www.laserresale.com** and they always have a wide variety of laser systems and accessories, although there is a high demand for surplus laser equipment and some of the stuff disappears fairly quickly, so you have to pay attention. An energy meter, however, only tells you the amount of energy in a laser pulse. It gives no indication of beam or pulse quality, and this is where the photodiode comes in. Later in this series, we will be looking at holograms, and you'll see then how important the beam and pulse quality are. This month though, we're going to use some of the information from last month to build a battery-operated optical pulse detector. With this unit, it will be possible to adjust the mirrors of a pulsed laser to get the highest energy and best pulse form out of the laser. I'll explain how to do this later in the article. A word of warning though, before we start. ***Under no circumstances shoot a laser beam directly into the photodiode.*** A chopped HeNe or diode laser perhaps won't do any damage, but any kind of pulsed laser will almost certainly destroy the diode.

Generating the bias voltage

In order to use a photodiode for high-speed optical pulse detection, we have to provide a high-voltage reverse bias to the diode. To do this, we're not going to use a mains-driven power supply, but rather use a battery and voltage multiplier circuit

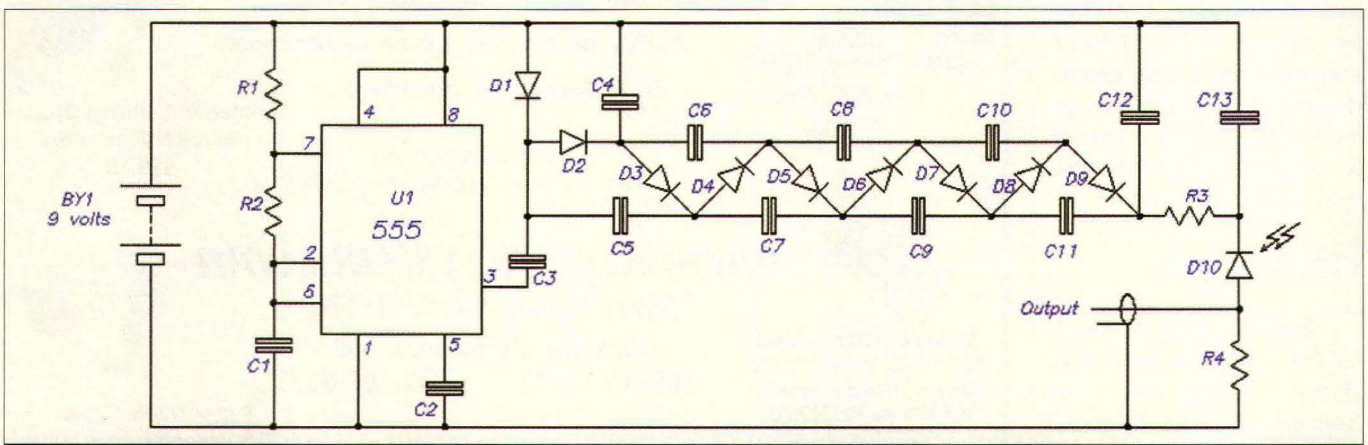


Figure 20-1: Schematic for the photodetector bias voltage generator.

for safety and portability. Since we don't require very high voltage and the diode doesn't draw any current, a nine-volt battery should last quite a long time. Turning to Figure 20-1, you'll see that there is really nothing complicated about the circuit for generating the bias voltage. We're using a nine-volt battery and an LM555 wired in astable mode in a diode pump circuit to boost the terminal voltage on the diode to about 35-40 volts. A resistor in series with the diode limits the available current to a safe level for the diode. In this circuit, the 555 timer generates a free running pulse waveform that feeds nine-volt pulses to the diode pump circuit consisting of diodes D1-D9, and capacitors C3-C12. The diodes and capacitors form a voltage multiplier that boosts the nine-volt pulse train to about 35-40 volts or so DC at the output terminal. This voltage is then applied as a reverse bias to the photodiode via R3 and R4. The output signal is taken from across R4, and is a positive-going signal.

Make sure you use a carbon resistor for R4. A spiral track etched in a carbon film resistor may have some small inductance that could influence the output during fast transitions, and possibly give false 'ringing.' You will notice that there is no gain stage (amplifier) included with this circuit. The reason for this is simple. Any gain stage introduces propagation delays and bandwidth limitations. To be more effective as a high-speed photodetector, it follows that any gain stage will alter the overall pulse waveform due to these effects, so the output will not be a true representation of the optical waveform. A gain stage could be added, but it would be a special design with critical components and circuit layout, in order to follow the high-speed transitions of the diode. Most op-amps have a limited bandwidth that is too low for the sort of rise times you may expect to find in pulsed lasers. In any case, the signal output will likely be large enough for most situations.

A word on the photodetector. In my unit, I used a photodetector from an IR communications set-up. It was a Motorola device, although the part number was abraded to the point I couldn't read it. However, I tried several small photodiodes from some broken VCRs that people gave to me for parts, and they worked very well in this application. So, if you have an old VCR that you can't find time to fix, make it do something else. There are several opto-coupled set-ups in a VCR that you could separate and try in this unit.

Construction

As always, you can use whatever construction

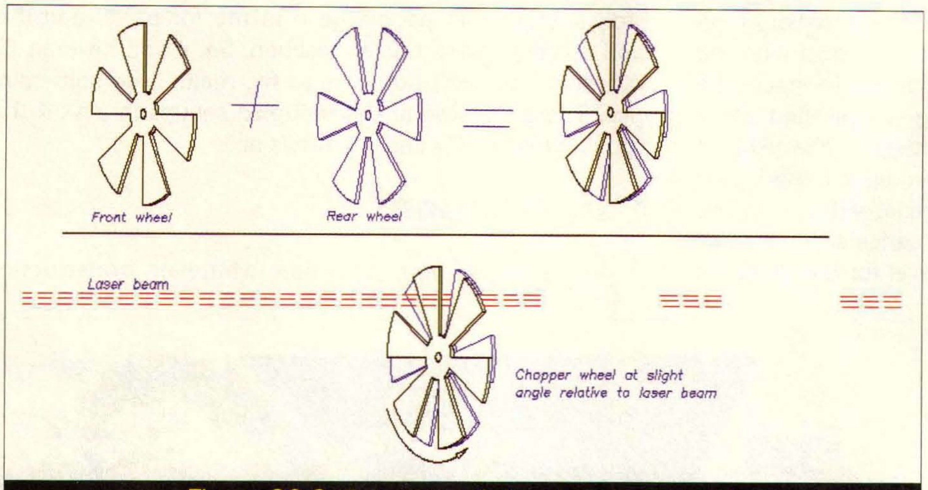


Figure 20-2: Principle of the chopper wheel.

method you feel most comfortable with. The circuit is very simple, and layout is not important. Try to keep everything compact and you'll get it all to fit inside a small metal or plastic box. Just make sure that nothing can short out, and keep jumper wires or links as short as possible. The photodiode should be mounted in the end of a piece of dark plastic tubing, or perhaps some other tube painted black. There is no need for a focusing lens in this device, as was used in the rev counter a few months ago.

Calibration and testing

Since this is a relative-reading device, it will not be possible to make any absolute value measurements, except for time duration. You can only compare amplitude results with other light stimuli. However, you can make some general assumptions and get good approximations. You will find that the results you get will depend on the power (energy) of the laser, the relative reflectivity of the target, and the orientation of the photodiode relative to the laser target. Remember, this photodiode is mainly useful for a pulsed laser, and pulsed lasers generally have brief, but very high intensity light pulses. It can be used with a CW laser too, but the beam will have to be modulated in some way, so that the relative amplitude can be assessed. One method of modulating a CW beam is to use a chopper wheel, and there are a few companies that make them (Coherent, Spectra-Physics), but they are not cheap.

The chopper wheel consists of a circular pair of plates that have segments cut in them at regular intervals. The plates are adjustable, so that the amount of light passing through can be increased or decreased, according to the needs. The plate assembly is spun at a fairly high speed using a synchronous motor, and placed in the beam path. The rotating blades interrupt the laser beam at regular intervals, causing a reduction in the average light output, as well as interrupting the laser beam and causing the beam to pulsate.

At the time of writing this article, I had just received my new Edmund Scientific catalog, and on page 183, there is an optical chopper wheel of this type. Instead of varying the spacing between the blades, the Edmund device uses separate, interchangeable wheels. It comes with a variable speed drive controller and sells for $950.00. Chopping frequency is variable from 5Hz to 20kHz. With high-power lasers, the portion of the beam that hits the rotating plates naturally causes them to heat up. However, the plates will dissipate a lot of the absorbed heat to the air as they rotate. In addition, part of the incident beam is scattered by the plates and further absorbed by the housing of the chopper wheel. The inside of the chopper box is usually finished matt black to better absorb this scattered energy. The output beam from the chopper is thus made into a rapid series of pulses, each pulse amplitude is at the CW laser power level. Figure 20-2 illustrates the principle of the chopper wheel. Here, a six-segment wheel is shown. Actual devices vary according to the manufacturer.

In use, the photodetector is normally used in conjunction with an oscilloscope to view the laser pulse in real time. For accuracy, the photodiode must not be allowed to saturate. If it does, then the relative amplitude readings will not be precise. To prevent saturation, the light reaching the photodiode junction must be limited, and this can be done in a number of different ways:

1. Point the diode in the opposite direction to the laser target, and allow multiple reflections from walls or the ceiling to energize the diode.

2. Cover the photodiode with multiple layers of semi-opaque material to filter out the light.

3. Use neutral-density filters in front of the photo-diode.

4. Use an iris in front of the diode.

5. Use a chopper wheel (for CW lasers).

6. Reduce the output from the laser.

Sometimes — as in the case of a high-power laser — it may be necessary to use a combination of the above methods. Commercial devices usually have some means of attaching an iris to the front of the photodetector, or perhaps a neutral-density filter (this is just a piece of varying density dark glass that, theoretically, has a constant attenuation factor regardless of the wavelength of the light, i.e., it is not wavelength selective). Figure 20-3 shows a typical output from this type of photosensor. In this case, the pulse is a single pulse from an Nd:YAG laser. The pulse energy was 300 mJoule aimed at a wall, with the photodetector pointed at the ceiling. Figure 20-4 shows a series of pulses, this time from a HeNe laser. The laser was fired through a home-made chopper wheel at a white sheet of paper, and the photodiode angle adjusted to face the paper a little off-axis from the target spot, so that it picked up a secondary reflection from off the wall of the tube surrounding the diode. The rounded edges of the pulses are due to the light being uncovered by the edge of the chopper as it rotates, and shows a gradual change in intensity before rapidly going full on or full off. In my chopper wheel, I used a cardboard disk with narrow slots cut into it. I then mounted this disk to a small DC motor running at about 2,000 RPM. The HeNe beam was then passed through the rotating disk about halfway from the center. If you don't have a HeNe laser or chopper wheel to test this device, you can always use your TV remote control. These devices normally use an IR light-emitting diode as the light source and make an excellent substitute for testing. In fact the photodiode is also a good device to use to check your remote controls. The output from these controls are a series of high-speed pulses that form a code to tell the TV or VCR what to do.

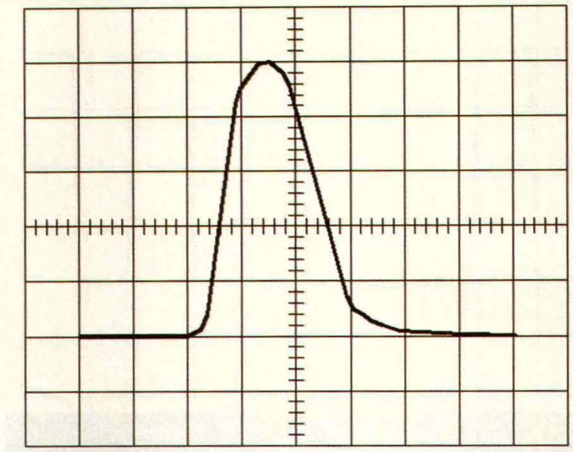


Figure 20-3: Typical output from the photodetector.

Parts List

U1	LM555 timer
R1	2.2k
R2	1k
R3	33k
R4	1k carbon

All resistors 1/4W metal film unless otherwise stated

C1	0.1uF
C2-C11	0.01uF
C12	1uF
C13	0.01uF

All capacitors 50V

D1-D9	1N914
D10	Silicon photodiode (see text)
BY1	Nine-volt battery

Miscellaneous:
Perfboard or PCB, hook-up wire, solder, battery clip, small plastic or metal box, plastic tube or heat shrink to fit around diode.

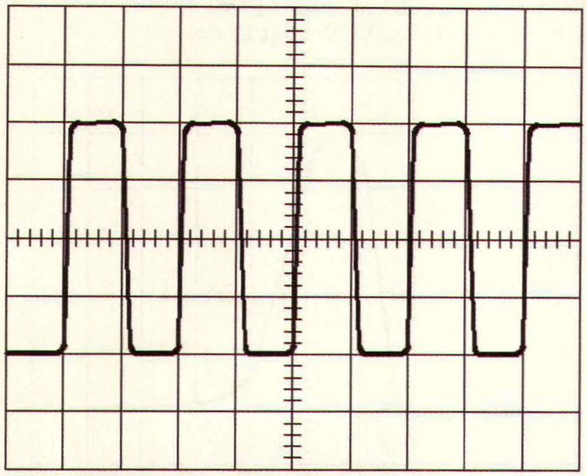


Figure 20-4: Output from the detector using a chopper.

Using the device

As always when using any kind of laser, think safety first and always wear protective eyewear, especially so with pulsed lasers. With a CW laser, your natural "blink response" will be quick enough to avert your eyes from the bright light. In a pulsed laser, the flash is several orders of magnitude brighter, and many times faster than your eye, and damage can be done before you realize it. To use the photodiode to align a laser, the laser must first be producing an output. The photodiode can then be used to "tweak" the mirrors for best pulse form or highest peak power. If you are using this device in conjunction with a pulsed laser, then the beam should be aimed at an energy-absorbing, diffusely-reflecting target (something that will absorb the energy of the beam and not allow sharp reflections from the surface). Depending on the laser power, you may use heavy card, matt black anodized aluminum, or any other suitable material. (I have used cinder blocks and house bricks when adjusting high-power CO_2 lasers, but that's another story!) Make sure that when you have a satisfactory set-up, that neither the target nor the photodetector can move. If anything starts to move, the photodetector can start receiving more (or less) incident light and give a false indication of true laser output. By taking a test shot or two, you'll get an idea of the intensity of the laser pulse by the relative amplitude of the output from the photodetector. Adjust the mirrors slightly in one axis and repeat for a couple of shots to see if the amplitude increases or decreases. Stop adjusting when the peak intensity is reached. Then go on and adjust the other mirror axis, and again repeat the test shots. By observing the oscilloscope trace (better if you have a storage scope), you will be able to tune your laser for sharpest peak or maximum energy fairly quickly after making a few test firings. If you are adjusting a CW laser, you will need to buy or make a chopper wheel, as suggested earlier. A single plate with a few slots cut in it will suffice, and will attenuate the incident beam enough to allow you to use perhaps a discarded ceramic tile (use the rough, back side) as the target material. Place the chopper wheel at a slight angle to the laser beam, so that there is no possibility of reflections from the wheel going back into the laser. See Figure 20-5 for a typical set-up. Pay careful attention to the reflected beam from the incident side of the chopper wheel — that energy is going to go somewhere! Stand a brick or a second ceramic tile alongside the chopper to prevent those reflections damaging anything, and as always, *keep your younger audience away.* Remember, you only get one set of eyes! Begin by aiming the laser through the chopper wheel and onto the target tile, and aim the photodiode directly at the spot where the beam hits the tile. If you get a high-amplitude pulse train on the scope, turn the diode slightly so that it is aimed off to one side of the target spot. The amplitude of the pulse should then decrease, and you should be able to adjust the laser mirrors for maximum output.

In this case, you will try to get the highest amplitude pulse. If you find you reach diode saturation, but are not sure that you have reached the real mirror peak, simply reduce the output power of the laser until you see the pulse amplitude go down. A lower power output from the laser is okay, because the alignment of the mirrors does not depend on the laser output, but rather the other way around. Peaking the mirrors can be done at any power level and will not change as the laser output power is increased. As always, if you have any questions regarding lasers or optics in general, or if you have any suggestions for future columns, please send me some email. I always answer everyone who contacts me, even though it sometimes takes a while. My email address is: **stanley.york@att.net.** NV

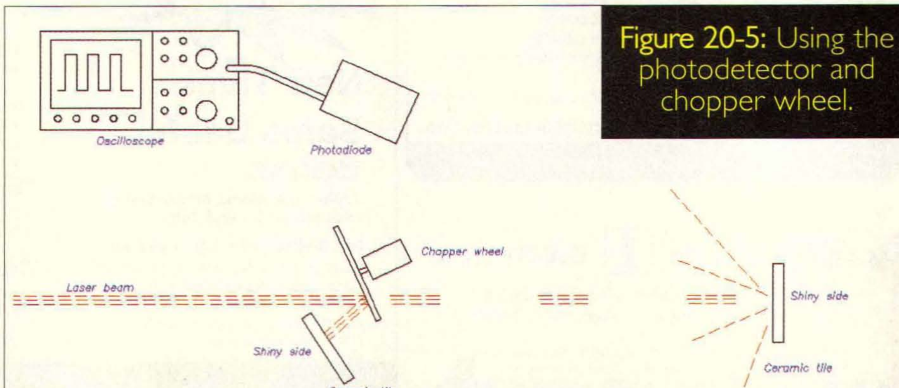


Figure 20-5: Using the photodetector and chopper wheel.

by George Whitaker

Basics For Beginners

Just for Starters

A Close-up Look at Soldering

Somewhere around 1949 or 1950, my father gave me a Triplett VOM and showed me some of the basics of using it. This was the starting point for a learning experience that continues today. Every experimenter, hobbyist, or professional has to start somewhere. And, that is what this series of articles is all about. For the next several months, we will be looking at some of the basics of electronics. If you are a novice, you may find that you already know some of the material we will be covering. On the other hand, you might find something that will open up a whole new world of understanding. It has been my experience that the understanding of one concept oftentimes makes plain a variety of other concepts. Now that we have established what this is all about, we need to consider another point. If you don't put it together properly, it isn't going to work. Therefore, in this first column, we are going to look at soldering.

Soldering is an art that, I will admit, I have been unable to master. A solder joint should be "pretty," as well as functional. I have been able to make them function, but personally, my talents are such that I have never been able to make them esthetically pleasing. However, making them functional is the purpose here and maybe you will be a little more artistic than me.

In soldering, the important thing is to get the solder to blend with the two items being fastened together. This action is a function of heat. If the heat is not adequately applied, you will have the solder sticking to itself and surrounding the item, but not actually blending with the item. With a little practice, you will be able to see when this blending occurs. Remember that you have to have both surfaces hot at the same time. Make sure the tip of the iron is touching the foil on the board and the wire at the same time. See Figure 1 for the correct placement of the tip. As you begin heating a wire with the soldering iron and apply a bit of solder, you will see the solder sitting on the outside of the wire in blobs. When the proper temperature is reached, the solder will suddenly turn shiny and spread to a thin layer on the outside and, on twisted wire, will actually go inside the twists. On a printed circuit board, you will see the solder become shiny and, instead of blobs, you will have a single mass that flows. The key word here is shiny. A good solder joint will have a shiny surface. If the heat is not adequately applied, it may appear to be holding, but will have a dull finish. A cold solder joint like this will turn loose and/or build up corrosion over a period of time and will come back to haunt you. Soldering, like any other art, should be practiced. I suggest you take a wire and strip the insulation back about 3/8 inch. Put your soldering iron on it and then touch a bit of solder to the tip of the iron at the point where it makes contact with the wire. The solder will stick to the iron, not the wire. Then, watch what happens. As you continue to apply heat, the solder will suddenly permeate the wire and, at the same time, will become very shiny. Until this action occurs, you might have some solder stuck on the wire, but it will not actually hold and it will corrode. Cut off the end and do it again several times until you can do it quickly and easily.

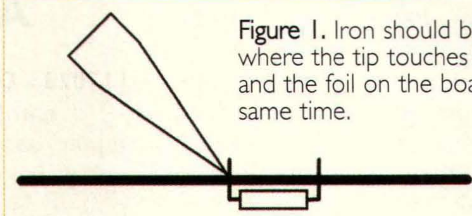


Figure 1. Iron should be placed where the tip touches the wire and the foil on the board at the same time.

What we have just done is "tin" a wire. Tinning a wire before actually fastening it will almost always make the soldering job easier and faster. There are a few cases where tinning might not be the best course of action. The addition of the solder might make the wire too big to go through a hole in a printed circuit board, or the stiffness it gives the wire might make it difficult to attach. However, in most cases, it is advised. Experience will show you when and when not to tin the wire. A brand new soldering tip must also be tinned before it is used. With a new tip, you should first bring it up to full heat and then apply solder until the tip is completely covered and is shiny. Next, wipe off the excess solder on a wet sponge. The tip should be smooth and shiny. Any time you have solder build up on the tip, you should use a wet sponge to clean it so that it again appears smooth and shiny. When a tip begins to age and gets pitted and black, you should file off the old surface with a fine tooth file and repeat the tinning process. Desoldering to remove parts or wires is much more difficult and problematic than soldering them on. In the next issue, we will get into desoldering. NV

QUESTIONS

I'm interested in building an interface for the basic controls of a camcorder with an "i.LINK" (IEEE1394) connection. And/or maybe the spec I'm looking for has something to do with OHCI. Are these specifications out in the open and where can I find them?

All I really want to control would be zoom, focus, and maybe exposure settings.

I know lots of camcorders come with a remote, but they're really hard to use while shooting. Maybe I should be thinking about hacking the remote?

#1031 **Bob Winningham via Internet**

Specifically, how is PPI (plan position indicator) radar data translated from the standard real-time display into a digitized format for viewing on a computer screen? A "how to" approach to this problem would be much appreciated; technical literacy is not lacking at our end. Thanks!

#1032 **Mark Ciancone via Internet**

ANSWERS

[12023 - DEC. 2003]

I want to bolt two computer tower cabinets together to have space for more drives. I want the power supply in the second cabinet to supply the power to the second cabinet's drives, but how do I get the power supply in the second cabinet to "turn on" without being connected to a motherboard?

Is there anything else I need to know in order to do this?

On an ATX power supply, pin 14 is used to turn on the power supply. You need to get this signal from the main supply to the slave.

Automotive-type insulation displacement connectors should work well in this application.

You need to tie the ground from one supply to the other (pins 3, 5, 7, 13, 15, 16, and 17).

It is also a good idea to provide a 10% minimum load on the unused voltages (3.3V, 5V, 12V).

Walter J. Heissenberger
Hancock, NH

[12022 - DEC. 2003]

I am trying to build a battery pack condition meter using an LM3914 chip to drive an array of LEDs. The problem is the max voltage of the LM3914 is less than the nominal charge voltage of the lead-acid battery pack.

#1 To use an LM3914 to represent a larger voltage than it can safely accept on its input, use a voltage-divider circuit to reduce the voltage sent to the input of the chip.

Simply use the voltage-divider formula to determine how much voltage you want to reach the LM3914, then scale the output accordingly.

For instance, if the chip could only handle 10 volts on its input and the voltage you want to measure is 20 volts full-scale, set up the divider circuit to divide the input voltage in half by placing resistors of equal value on the top and bottom of the network. To give one-third the input voltage at the output, make the resistor on top twice as large as the bottom. Use the formula on the diagram (Figure 1) to scale it for your application. Keep the resistor values in the 10s of Kohms range to keep the current draw and the power dissipated in the divider network low.

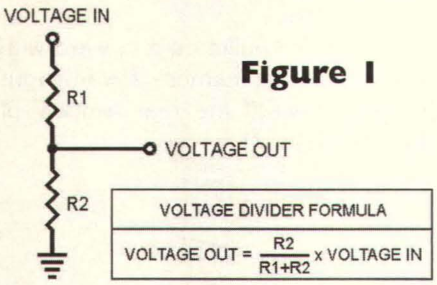


Figure 1

Jeff Burger
via Internet

#2 Use a zener diode in series with the power to the LM3914 to drop the voltage to its operating range. The battery pack is essentially dead when the voltage drops by 20%, so set the reference voltage to 20% of the full charge voltage and use another zener to bring the input voltage down to 20% of the full charge voltage. The LEDs will all go out when the battery is dead.

Russell Kincaid
via Internet

#3 Since the LM3914N is rated at 25 volts, I assume you want to test a battery of greater than 24 volts.

The circuit shown (Figure 2) for the LM3914N can be adapted to nearly any voltage with the change of some of the component values.

The ratio of R1 to R2 samples the battery voltage to give an indication on the LEDs connected to the IC. R2 is 2K ohms 1/4 watt 5%. To determine the value of R1, subtract 1 from the number of cells. For example, a 24-volt battery has 12 cells. So the ratio of R1 to R2 is 11:1. Now multiply the value of R2 (2K) by 11 to get 22K. D12 is a zener diode. I recommend a one-watt, 12-volt such as the 1N4742A. The value of R7 is calculated to drop the full charge voltage of the battery to the zener voltage at 25 mA. For a 24-volt battery, the full charge voltage is close to 29 volts. R7 = (29-12)/.025 or 680 ohms. Power rating = .025 x .025 x 680 or 0.425 watts. For good practice, use a one-watt resistor.

The other components are:

C1 — 10uF electrolytic at higher than maximum charge voltage
C2 — 2.2uF tantalum
D1 through D10 — LEDs
D11 — 1N4007 diode
D12 — 1N4742A
R2, R3, R4 — 2K 1/4W 5%
R5 — 750 ohm 1/4W 5%
R6 — 1K trimpot
U1 — LM3914N

As shown, the LM3914 is set up for the dot mode to conserve power.

R6, the trimpot is adjusted so that either the cutoff voltage or the full charge voltage is shown. D1 shows the lowest voltage, while D10 shows the highest voltage. Adjusting R6 (1K) moves both the reference Lo and reference Hi slightly. Adjusting the pot so that D1 is illuminated to the cutoff voltage (number of cells x 1.9) tells when the battery needs to be recharged. Adjusting R6 when D10 is illuminated shows the battery is fully charged (number of cells x 2.4).

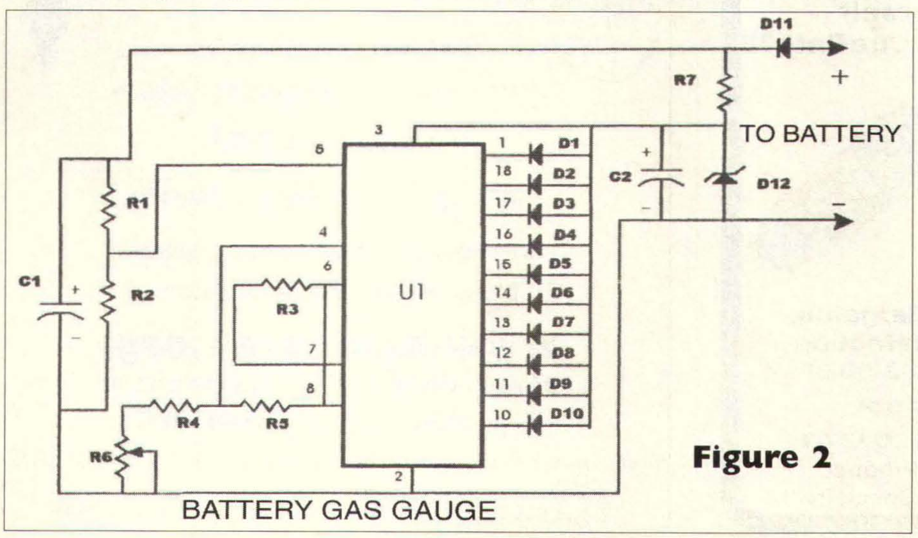


Figure 2

BATTERY GAS GAUGE

The current drawn from the reference out pin 7, determines the LED current. In this case, the LED current is about 8 mA. If for some chance the battery voltage is less than 24, then R7, D12, and C1 can be eliminated, and R1 value is calculated as before. No LED current resistors are required as the LM3914N provides constant current to the individual LEDs.

Ned Stevens
Grantsville, UT

[12021 - DEC. 2003]

I need ideas on how best to convert a logic analyzer that uses the CP/M operating system to one that will run under Windows or DOS. The original logic analyzer (a Kontron KLA-64, 64 ch., 100MHz) is run by an 8085-based CPU/control board that affects all control functions through parallel I/O ports. I propose to replace the dated 8085-based CPU/control board with a newer embedded processor board and run it under DOS or Windows.

#1 Although DOS was based on CP/M and the 8085 and 80x86 processors share common roots, CP/M programs will not run under DOS and CP/M will not run on an 80x86 platform. The best solution is to use a CP/M emulator, which will run CP/M programs in a DOS window, and a disk driver to read CP/M under DOS. A 5.25" low-density drive will be necessary, also.

A popular CP/M emulator was UniForm, and its companion disk driver was UniDOS. Both programs are apparently discontinued, but they show up on eBay frequently.

A current emulator and disk driver are available at reasonable prices from **DYNACOMP, Inc.**, 4768 Route 89, Romulus, NY 14541. Email: **info@DynacompSoftware.com**. Phone/fax **315-549-7118**.

Joe D'Airo
West Islip, NY

#2 This would be a big project. You could run the CP/M software on a Windows machine only by using software emulation. That would give you only the same functionality you have now, but faster.

There are open source CP/M emulators for Windows, but you would have to modify the emulator to add the custom hardware ports built into the analyzer, then write DOS/Windows device drivers to talk to custom hardware that you build.

The display would also be a problem. There are no standards for graphic displays on CP/M, so you would have to emulate that, too.

With much less effort, you might be able to speed up the existing processor board. Most 2MHz CP/M machines will run at 4 or 6 MHz with faster memory, a new CPU chip, and replacement of a few key 74LS-type chips with 74S equivalents.

Do you have a schematic? You can usually borrow a faster clock pulse from the clock divider.

Mike Ingle
Camarillo, CA

[12026 - DEC. 2003]

I have a Bullet Camera that I intend to install in the back of my car for a rear-view display.

How can I mirror or reverse the camera output horizontally so that "left" on the screen is "left" in the car?

#1 The circuitry required to mirror a video signal is a bit complicated. It would require a scan converter-type design with lots of video memory and a means to grab a frame and sequence it out "backwards." However, there are easier ways to do this.

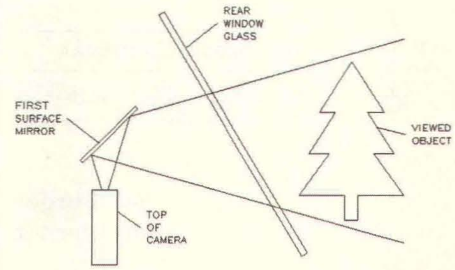
If your display is a standard CRT, then you can reverse the horizontal deflection yoke connections. This is a simple modification and involves a little bit of soldering.

If it is a TFT/LCD type display, then many of the automotive models have a image reversal feature. It is usually a jumper or switch and is used in applications just like yours. Not all displays have the feature, so check the display's specs before you buy it.

T. Black
Folsom, CA

#2 Here's a relatively low-tech solution for your problem. Simply use a piece of first-surface mirror (commonly used in laser experiments) in a periscope-type arrangement.

Point the bullet cam upward with the top of the camera toward your subject (toward the rear window of the vehicle).



Mount the mirror above the camera angled so that the camera "looks" out the rear window. Since the camera "sees" a reflection, the image will appear to be reversed.

Mount the mirror with the reflective side toward the camera to avoid any ghost images from the mirror's glass.

The mirror and camera mounting scheme is up to you ... it could be wood, plastic or metal. The mirror mount itself could also be adjustable or fixed. Keep in mind that if it's adjustable, it may need to be adjusted periodically, however. Also, try not to touch the reflective side of the mirror, since it scratches easily.

Jeff Burger
via Internet

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