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Circle #72 on the Reader Service Card.

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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:

Kudos to Lou Frenzel for the "Open Communication Part 3: Broadband Communications" article. It is an extremely well-written article and covered all of the key points in a logical progression.

Mike
via Internet

Dear Nuts & Volts:

Gerard Fonte seems to have missed the point that junction capacitance does not stop varying when an LED is back biased — it continues to be inversely related to the virtual gap between the capacitor plates.

William Vonwicklen
Oxnard, CA

Response from Gerard Fonte:

Mr. Vonwicklen is correct in stating that a reversed-biased LED will vary in capacitance. The table I have shows that an IR LED will vary from about 100 pF to 50 pF going from 0 to minus eight volts. However, that was not my point.

My points were to show that a very large capacitance change occurs with a forward voltage change. In this case, from about 100 pF to 400 pF going from 0 to plus 1.2 volts (the threshold voltage). This was also to suggest that an LED might be used to replace the 365 pF tuning capacitor in old AM radios. The second point is related. That is the positive voltage is applied to the anode rather than the cathode (as with variable capacitance diodes) for such a change. Thanks for the opportunity to respond. I always appreciate feedback from readers.

Gerard Fonte

Dear Nuts & Volts:

Thanks for G. Randy Slone's excellent article in Feb. 2003 *Nuts & Volts* about the 100W audio power amplifier. I don't think I have ever read a more thorough description of a circuit. The article made me uncomfortably aware of large gaps in my knowledge of solid-state electronics, but Mr. Slone has a way of explaining things that kept my attention long enough so that some new understanding actually soaked in. Very interesting and educational reading.

Max Carter
Wheatland, WY

Dear Nuts & Volts:

Although the MITS Altair 8800 computer had a tremendous impact on the development of hobby computers, let's give predecessors their due. Ed Driscoll's history (Jan. 2003, pg. 26) misstates that the Jan. 1975 cover of *Popular Electronics* launched an industry. Actually, the July 1974 issue of *Radio-Electronics* magazine featured the Mark-8, a hobby computer based on Intel's first eight-bit processor, the 8008.

If any magazine cover launched a revolution in computing, that one should get the title. Also, let's give credit to lesser-known computers such as the Scelbi and computer groups such as the American Computer Society. Just because people can't remember or have no knowledge of these historic efforts, they still played important roles in getting us to where we are today.

Jon Titus
via Internet

Dear Nuts & Volts:

I am a technician with Digi-Key Corp. and I had a customer point out an error in one of TJ Byers articles. The article appeared in Oct. 2002, page 38, titled "Fixing Broken Keypads."

TJ Byers states in the article that the rubber keypad repair kit CW2605 contains 3.3 oz. of repair material and CW2610 contains 11 oz. of repair material. This is wrong, the CW2605 contains 3.3 grams or 0.12 oz. of repair material and the CW2610 contains 11.1 grams or 0.39 oz. of repair material.

Bruce Olson
Technical Support
Digi-Key Corp.

The End of An Era

* **Poptronics Ceases Publication:** *Poptronics* magazine — which evolved from the former *Popular Electronics* and *Electronics Now magazines* — ceased publication with the January 2003 edition (Vol. 4, No 1). "After 94 years of publishing electronics magazines Gernsback Publications is no longer in operation," said Larry Steckler, *Poptronics*' editor-in-chief and publisher.

As many of you may already know, *Nuts & Volts* has agreed to complete existing subscriptions to *Poptronics*. We welcome our new readers and hope you enjoy *Nuts & Volts!*

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

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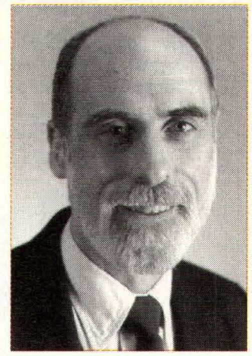
Micro Memories

Happy Birthday Internet!

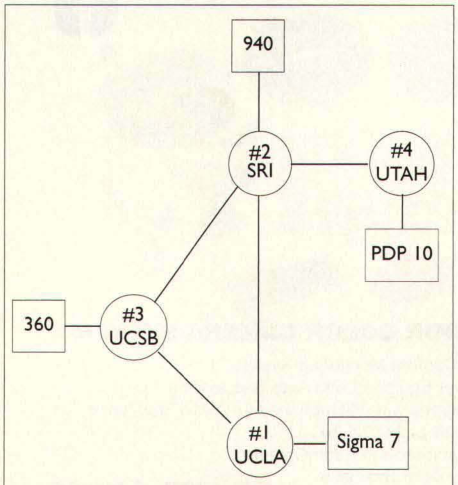


Vinton G. Cerf
Courtesy of the Computer History Museum.

On January 1, 2003, while you and I were celebrating a new year, the Internet was quietly enjoying a milestone date of its own: The 20th anniversary of its switchover to the TCP/IP networking standard, which radically transformed it from a network that connected military and university mainframes to the sprawling "information superhighway" that reaches into hundreds of millions of homes, businesses, and schools, and has radically transformed the lives of its users.

The original Arpanet first went online on October 1, 1969. As we've written about in past columns of Micro Memories, the first computers were created immediately after World War II. By the 1960s, serious science fiction writers like Arthur C. Clarke, visionaries like Marshall McLuhan, and futurists like Alvin Toffler were writing both about the future of computers and the ongoing effects that technology was having on everyday lives.

One thing was apparent to all of them: computers had the potential to shrink the size of the planet, especially if they were joined together via some kind of interconnected network. McLuhan wrote about "a global village" in the mid-1960s; the Internet sealed the deal when Mosaic — the first graphical browser — became available in 1993.



1969 FOUR-NODE MAP.
Courtesy of the Computer History Museum.

Arpanet: The Internet's Ancestor

What none of those late 1960's writers realized was that the US government was thinking similar thoughts. The government's concern, however, was not with creating some sort of global village, but surviving a nuclear war. In 1998, I interviewed Louis Rossetto, the founder, then CEO and executive editor of *Wired* magazine — in his office in San Francisco — and asked him how the Internet began.

"It was set up by Arpa, which was a research arm of the defense department, to connect researchers together in an atomic bomb-proof network. So instead of having direct landlines, they had a distributed network that passed messages along. So that if you took a node out of the network, the messages could route around that node, in the event of a nuclear attack. So if one computer went down, it didn't screw up the whole system.

It gradually became popular in the academic community. People used it to communicate with each other, and then, in effect, to publish on it. And then gradually more and more people got interested in using it for communications and ultimately for publishing, and now for commerce."

Arpa stands for the Advanced Research Projects Agency, and it was founded in 1958. The original name changed in 1972 to Defense Advanced Research Projects Agency, to reflect its assimilation into the Defense Department. Arpanet — established in 1969 — was the first wide-area computer network and the direct precursor to the Internet. Arpa built it as a research-sharing tool. By the 1980s, Arpanet was overshadowed by the National Science Foundation's high-speed NSFNet backbone and the regional networks connected to it. Around this time, people began to think of this interconnected collection of networks as an Internet.

"I Survived the TCP/IP Transition!"

What made that change from a military and collegiate networking scheme to a network open to virtually anyone (and eventually everyone) was the changeover in 1983 from NCP (network control protocols) — the original networking standard that Arpanet ran on, which dated back to its beginnings — to its now familiar TCP/IP (short for transmission control protocol/internet protocol) format on January 1, 1983. Prior to that, the number of computers connected to what was then known as Arpanet was below 1,000 and the number of Internet hosts was at about 200. It's not a coincidence that in 1984, the number of hosts cracked 1,000. As of 2002, there were 172 million host computers supporting some 600 million subscribers!

TCP (Transfer Control Protocol), outlined in a 1974 paper by Vinton Cerf and Robert Kahn, was originally introduced in 1977 for cross-network connections, and it slowly began to replace NCP within the original Arpanet. TCP was faster, easier to use, and less expensive to implement than NCP. In 1978, IP (Internet Protocol) was added to TCP and took over the routing of messages.

Someone once said that "the great thing about you Americans is that you have so many standards to choose from." But it was obvious to the original users of Arpanet that a single set of standards would speed the growth and acceptance of the network. TCP/IP was chosen to provide a bridge for small networks to connect to the Internet much more readily than they could with NCP. The links branched in every direction, hugely increasing the number of people connected within a single, broad system of information and communication.

Some sites were given a grace period of a few months, but by the spring of 1983, any system that had not converted to TCP/IP was bumped off the network. Six months after the switchover, Arpanet was split into the two subnets, Arpanet and Milnet, which became the side of the network that represents the military side of the original Arpanet, carrying non-classified US military traffic.

Bob Braden — another Internet pioneer who was active in the Arpanet Network Working Group in the 1970s and contributed to the design of the FTP protocol — recently told Australia's *Sydney Morning Herald* that "there may still be a few remaining T-shirts that read, "I Survived the TCP/IP Transition."

People sometimes question that any geeks would have been in machine rooms on January 1. Believe it! Some geeks got very little sleep for a few days (and that was before the word "geek" was invented, I believe)."

The other gradual advantage of TCP/IP is that it opened up the Internet for non-academic or defense users. Prior to 1983, most early adopters who had connected their PCs to modems (see the Nov. 2001 Micro Memories) weren't visiting the Internet. They were either connected to small regional bulletin boards, or proprietary services such as CompuServe or The Source.

But a seemingly minor change set in motion the Internet we know today. So Happy Birthday, TCP/IP! And Happy Birthday, Internet! **NV**

TechKnowledgey 2003

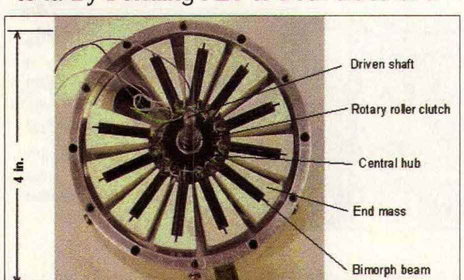
Events, Advances, and News From The Electronics World

Advanced Technologies

New Motor Offers Flat Configuration

With support from the Defense Advanced Research Projects Agency (DARPA), engineers at Penn State University (**www.psu.edu**) have developed an interesting flat motor for use in limited spaces. The prototype runs at an unloaded speed of 760 RPM and provides torque of 0.4 newton-meters (0.3 foot-pounds). The inventors believe that the patented motor can be used to drive changes in the camber of airplane wings or fins, essentially shape-shifting the curvature of the wing or fin surface. In alternative formats, the motor could work in tightly integrated spaces, for example, as the drive element in thinner, lighter laptop computers or in manufacturing equipment that processes things by moving or shaking them.

The motor works by converting the bending motion of a "smart" material into the turning of a shaft. The material in this case is PZT (lead zirconate titanate), an inexpensive, commonly-available piezoelectric that elongates when an electric field is applied to it. By bonding PZT to both sides of a tiny, flexible, metallic strip, one obtains an "arm" that can bend to the left or right in response to an electric field.



Penn State's flat motor uses piezoelectric technology to produce high torque at low speeds. Photo courtesy of Jeremy Frank, KCF Technologies.

In the motor, 12 such arms are arranged in a starfish configuration around a central shaft. When the arms are electrically stimulated, they all bend in the same direction. A mechanical clamping system then holds the ends of the arms in place so that, when the electrical field is removed, the shaft turns like a ratchet. Repeated stimulations generate the rotary motion. Components for the prototype cost less than $150.00 off-the-shelf. It is estimated that an optimized version of the flat motor might cost as little as $10.00 in mass production.

Artificial Retina May Restore Sight

There presently is no cure for degenerative retinal diseases that have caused hundreds of thousands of people to lose their sight. However, researchers at the US Department of Energy's Argonne National Laboratory (**www.anl.gov**) — in collaboration with four other national laboratories, two universities, and a private company — are moving a step closer to developing an artificial retina that may restore sight to people who have been blinded by these diseases.

The goal of this consortium is to work together to create an artificial retina that would effectively replace the destroyed rods and cones in the eye with a light receptor and optical signal converter. The concept is based on a tiny camera and RF transmitter (mounted on a patient's glasses) that capture images and transmit the information to a microchip. The image is then transmitted as electrical pulses to the retina via an array of implanted electrodes. From there, the information is processed and passed along to the brain.

Argonne's role in the project relates to development of the electrode implants, which are based on a patented ultrananocrystalline diamond technology developed at Argonne for the packaging of implantable electronics and as electrode material. According to material's scientist Orlando Auciello, ultrananocrystalline diamond has a unique combination of properties including the highest hardness of any diamond film, an extremely low-friction coefficient and surface adhesion, very high electron emission, chemical inertness, extremely high conductivity when doped with nitrogen, biocompatibility, and surface functionalization. All these

Argonne material scientists Orlando Auciello (right) and John A. Carlisle work with a new microwave plasma system that grows the diamond films used in artificial retina research. Courtesy of Argonne National Laboratory.

properties are the result of the unique microstructure of ultrananocrystalline diamond, characterized by grains that are just two to five nanometers in size.

The project is funded for four years, and a functional artificial retina is still a long way from a reality. But as summed up by Auciello, "The artificial retina is very appealing to scientists because it contributes to improving the way of life for people. Having the ability to see is something too many people take for granted."

Computers and Networking

Discarded Computers Yield Many Secrets

A recent study conducted by two students at the Laboratory for Computer Science of the Massachusetts Institute of Technology (**www.mit.edu**) indicates that we need to be a little more careful about how we discard computers and disk drives. Scavenging through the data left on 158 used drives, the students found more than 5,000 credit card numbers, detailed personal and corporate financial records, numerous medical records, and many gigabytes of personal email and pornography. They bought the drives for less than $1,000.00 from eBay and other sources of used hardware.

Data had been properly removed from only 12 of the units. Considering that more than 150 million disk drives were retired from service in 2002, it becomes apparent that a great deal of confidential information is floating around and is easily obtainable. The lesson is that, before disposing of a disk drive, you need to run a utility that overwrites every data block; simply deleting the data is not sufficient, as it can be recovered with a common "undelete" program or by reading individual data blocks using special tools.

Is Your Web Site a Patent Violation?

If you operate a web site that employs frames (that is, if clicking on an icon causes part, but not all, of the display to change), a company called SBC Intellectual Property soon may come knocking on your door to ask for money. Apparently, this division of SBC Communications, Inc. (**www.sbc.com**) now owns a patent that was granted to Ameritech Corp., in May 1996 (patent no. 5,933,841), plus another related patent (6,442,574). The patents cover a "structured document browser," and SBC claims that it includes not only the browser, but all web sites that enable such browsing to occur.

In case you don't recognize the company, SBC Communications is the second largest local telephone company in the US, with 60 million phone lines in 13 states. It also operates Cingular Wireless, which has 22 million subscribers in 38 states. SBC has reported annual revenues exceeding $40 billion.

In its initial attempt to collect royalties, SBC appears to have targeted a relatively small and defenseless entity — The Museum Tour Catalog (**www.museumtour.com**) — which sells "quality, educational toys and museum gifts that stimulate curiosity, provide aesthetic pleasure, and enhance the joy of learning." The items come from 22 national science centers, zoos, and aquariums.

In a letter sent to Museum Tour, SBC included a table of approximate royalty payments it expects to receive. If you qualify for the preferred rate and have annual revenues of $100,000.00, you have a choice of paying $527.00 per year or a flat fee of $1,581.00. But if you don't qualify, you face the base rate of $5,270.00 per year or a flat fee of $15,811.00. Apparently, SBC also has its eye on the upper end of the economic scale. According to the table, if your company grosses $10 billion and does not qualify for the preferred rate, you'll have to cough up either $16,666,667.00 per year or a one-time payment of $50 million.

The Internet community has reacted to SBC's claims with a combination of fear, loathing, and disbelief. An exemplary statement appears on the Larkware web site (**Larkware.com**), which says, "This is so staggeringly stupid that it's difficult to know where to start, other than with the obvious observation that the US Patent and Trademark Office has no business granting this sort of junk patent." Can this affect millions of web sites, including yours? Could be, but the dynamics may change when SBC starts sending invoices to Microsoft, IBM, General Motors, and other large corporations that have the resources to fight back.

Circuits and Devices

Projection Keyboard Targets Mobile and Wireless Devices

An interesting concept from Canesta, Inc., is a projection keyboard for mobile and wireless devices such as smartphones, PDAs, tablet PCs, and cell phones. Using the Canesta chipset, original equipment manufacturers (OEMs) will be able to incorporate a full-sized keyboard and mouse that exist as projected beams of light rather than hardware. The keyboard is projected onto a flat surface in front of the mobile device, so you will have to drop back to the built-in keys if you don't have a flat surface available.

The keyboard is implemented by means of a three-dimensional sensor that tracks moving objects in the vicinity of the sensor chip. The packaged sensor — a module about the size of a pea — resolves a user's finger movements within the projected image of a keyboard, translates those movements into "keystrokes" on specific projected keys, and processes the movements into a stream of serial keystroke data.

The sensor module works with two other miniature components: a pattern projector and a small infrared light source. The pattern projector uses an internal laser to project the keyboard image. The keyboard may be the standard QWERTY English keyboard, any non-English layout, or even non-Roman character set, and custom keypads can be created for specific applications.

As of this writing, the device is not available in any commercial products, but NEC is evaluating the technology for use in its product line. Companies that are interested in employing the technology can buy an OEM Toolkit that provides the basics. A data sheet describing the complete details of the OEM toolkit is available online at **www.canesta.com/downloads/toolkit.pdf.**

Canesta's chipset will allow full-size projection keyboards to be incorporated in mobile devices. Courtesy of Canesta, Inc.

Headphones For Serious Audiophiles

Falling into the category of "sexy products for people who have too much money" is Sennheiser's Orpheus headphone system (**www.sennheiserusa.com**). The hand-made apparatus combines a vacuum tube amplifier with electrostatic headphones and features a 1 µm, gold-plated diaphragm and an on-board dedicated bitstream digital-to-analog converter.

Specifications for the headphone section include distortion of <0.01 percent, nominal sensitivity > = 98 dB at 1 kHz, and frequency response from 7 to 100,000 Hz (-10 dB). The latter seems like a bit of overkill, considering that your ear is most sensitive in the band from about 2,000 to 5,000 Hz and probably can't detect much over 20,000 Hz. But if you put the headphones on your dog, he should really appreciate the high frequencies. And let's admit it. If you buy the Orpheus, your main goal is not a more realistic rendering of Julio Iglesias' latest CD. It is to impress your friends with the satin-lined, hardwood storage box, the gaudy wood-and-chrome amplifier, and the list price of $14,900.00.

Industry and the Profession

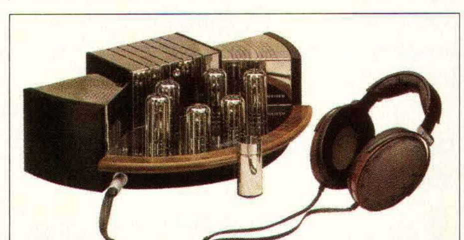
Alternative Energy Not a Great Alternative

If you have been looking forward to the day when renewable energy sources provide a clean alternative to fossil fuels, a recent analysis generated at Cornell University (**www.cornell.edu**) will not be good news. According to Prof. David Pimental and associates, even if implemented to the highest practical extent, renewable energy sources can replace only about half the US consumption of oil, natural gas, and coal. Furthermore, the analysis states that fully developed alternative energy systems (including hydroelectric power, solar and wind power, and biofuels) would occupy up to one-sixth of the country's land area, causing a whole new set of environmental problems.

The ecologists reviewed 10 alternative energy sources, but deemed two of these (geothermal systems and biofuels) not truly renewable and sustainable. The other eight alternative energy systems reviewed in the analysis included hydroelectric power, biomass energy, wind power, solar thermal conversion, photovoltaic systems, hydrogen and fuel cells, and passive heating and cooling of buildings. Although emphasizing various disadvantages to most of these energy sources, the report was particularly upbeat about biogas generation, whereby burnable methane is produced in "digesters" by microbes that eat animal dung. If your family has at least 50 cows in the back yard, you can install a digester for less than $1,000.00 and produce biogas at an electricity price equivalent of $.06 per kilowatt hour. If you have moved off the farm, however, you're just going to have to cut back on everything.

IBM, Hitachi Form New Company

IBM (**www.ibm.com**) has completed an agreement to combine its hard disk drive operations with Hitachi's, forming a new company called Hitachi Global Storage Technologies. Under the agreement, Hitachi bought the majority of IBM's HDD-related assets for $2.05 billion. Hitachi paid 70 percent of the purchase price to IBM immediately and will pay the remainder over the next three years. The new company will be located in San Jose, CA. **NV**



Sennheiser's Orpheus headphones provide premium performance — at a price. Photo courtesy of Sennheiser Electronic Corp.

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All models come with matching 2.4 GHz receiver.
Comes with concealed camera/transmitter, matching receiver, 1 year warranty, and 30 day MBG. Lens not included.
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0.0003 LUX! SEES IN VIRTUAL DARKNESS!
This tough style is the #1 choice of law enforcement!
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• Single channel digital video recorder
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• Incredible 0.375" square X 0.625"
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Comes with power cable, complete instructions, 1 year manufacturer's warranty and 30 day money-back satisfaction guarantee.
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STILL PHOTO SURVEILLANCE SYSTEM
Capture stunning images of wildlife ...or bad guys red handed!
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Comes with security chain, magnetic activation system, camouflage cover and 1 year warranty. Also available in tree bark and vandal resistant.
SPC-1 Still Photo Surveillance Camera System $449.95
• Stores 64 images in memory
• Weatherproof case
• Built-in IR lighting
• 0 lux rating up to 15 feet
• Pixel resolution of 320 X 240
• PIR motion activated
• Runs on12 volts DC or 6 AAs
• 1 year warranty, 30 day MBG
Comes with camera, video cable, 12 volt power cord, mounting strap, 1 year warranty and a 30 day MBG.
CVL46 Digital Flash Memory Camera System $319.95
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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:
Plenty of stuff to get the novice hobbyist started. How to program digitally-controlled devices without a PC using parts from a junk box. 11W stereo amp for $5.00, and a new twist on the 555. Find an OEM using the FCC ID number.

A PC Interface Without The PC

Q. I'm wondering if you can provide any information regarding the control of the LM1971/LM1972/ LM1973 family of digitally-controlled audio attenuators. The National Semiconductor catalog shows a typical application. Unfortunately, no control circuit is given for an interface with the three control pins of load, clock, and serial input. I realize this question might be a little more than can be answered in a single column, but if you could direct me to a book or an article that describes the digital control of these ICs, it would be very helpful.

Al Lovecky
via Internet

A. You might notice that in my intro to this column, I state "I answer all aspects of electronics ... and anything else of interest to the hobbyist." At first, I purposely sidestepped questions like this by providing a datasheet — or other source — simply because the majority of readers had little or no interest in this field at the time.

Over the years, the components have become increasingly more microcontroller "friendly," and our readers more computer savvy. And I've increasingly been answering more of these kinds of questions. While what you ask takes it up a notch, I feel obligated to answer it in terms that both the novice and experienced reader can understand. Here goes.

Nowadays, most microcontroller interfaces are of the serial variety. That is, the control and data bits are paraded in one after the other like the box cars of a train, rather than loaded in via individual inputs like cars entering the toll booths of a highway. There is more than one serial interface. The LM197x series uses a protocol (way of doing things) called uPot that requires two bytes (a byte is eight bits). One byte addresses (selects) the "potentiometer," AKA attenuator, being controlled (the LM1971 has one pot, the LM1972 has two, and the LM1973 has three). The following byte specifies how much attenuation each pot should insert into the circuit. The timing sequence looks like this (Figure 1).

First, the Load pin is pulled low. Although a microcontroller is normally used to set this pin low, you can do the same thing using a RadioShack SPST switch. Next, the binary code used to set the attenuation of the LM1971 is entered via the Data pin using 16 clicks of the clock. Once the code is loaded, the Load line is returned high, and the LM1971 proceeds to process your command. Hey, that's not such a big deal! It just sounds complicated when the word microcontroller is mentioned.

Figure 2 shows how to program

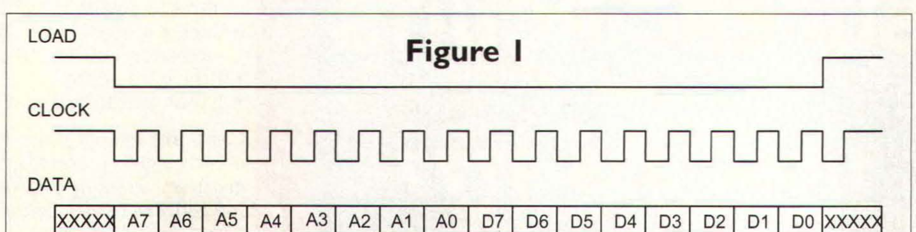


Figure 1

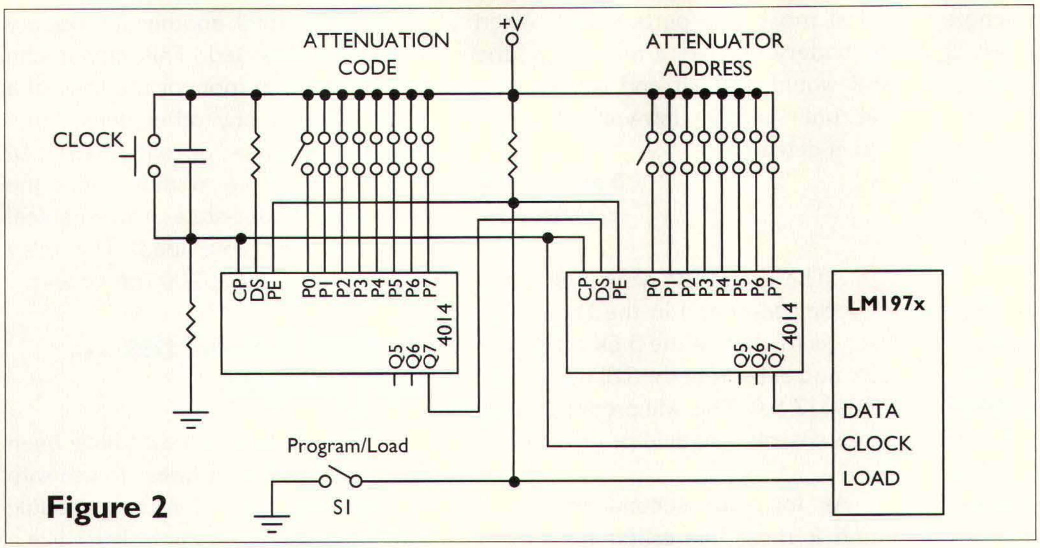


Figure 2

the LM197x without a microcontroller. With S1 open, the Attenuation Code and Attenuator Address switch are set to represent the code you wish to send to the LM197x chip. Close S1 and press the Clock button 16 times. Open S1 and you're done. That's it. Of course, the circuit is very rudimentary and can be improved upon vastly with a programmed clock and display, but you get the idea.

Bottom line is that computer interfaces shouldn't scare you. By knowing what the device expects in the way of voltages and sequence of events, you can "program" any computer-dependent chip using parts you probably have in your junk box.

New Columns Ring In The New Year

Q. I have been a subscriber of *Nuts & Volts* for almost a year now, and have a basic knowledge of electronics. I find the magazine most interesting, but have to admit that I don't know much of anything regarding these so-called BASIC Stamps or other controlling devices. So where does a guy like me begin to learn about these devices and build the various projects that are featured each month?

Jake
via Internet

A. Your timing couldn't have been better. Starting with the Jan. 2003 issue, the *N&V* editors added three new columns, two of which are targeted directly at you. *"Just For Starters"* builds a good platform in the basics as you begin your journey into the world of electronics, including topics like how to solder and where to buy. *"Let's Get Technical"* is designed to whet your appetite in the more advanced subjects — like analog and digital, microcontrollers, computer arithmetic, and networking — while examining theories and applications.

Two other recently added columns are devoted to *"Robotic Sources,"* which shows you where to get information, kits, and parts, and *"In The Trenches,"* devoted to design engineers facing real-world problems and solutions. As you can see, when we say "Everything For Electronics" we mean it. Glad to have you aboard.

Cheap Audio Chip Boasts Premium Sounds

Q. My 70-watt Adcom power amplifier has been working fine for many years and I expect it will go on for a long time. But I don't like it that loud, and would like to try something with less power. Do you have any circuits for a one-transistor, single-ended power amplifier of about 2 to 10 watts? Something with negative feedback, a high dampening factor, and low distortion using an easy-to-get transistor, like a 2N3055. Also, a design which has thermal runaway protection. A power supply diagram isn't needed — I know how to do that.

Charles Wolf
San Francisco, CA

A. I can do better than that. National Semiconductor makes the LM4752 — a stereo 11-watt power amplifier housed in a TO-220 plastic package that's smaller than the TO-3 metal case of a single 2N3055. Better yet, you can buy it from Digi-Key (800-344-4539; **www.digikey.com**) for just $2.67. Toss in a handful of passive components, and you have a far better amplifier than a single 2N3055 can make — thermal protection included — for under $5.00 (Figure 3).

The LM4752 datasheet, which you can download from the National Semiconductor web site (**www.national.com/pf/LM/LM4752.html**), includes a printed circuit board foil pattern and parts placement guide that simplifies the fabrication of a high-quality stereo amp.

New Twist On 555 Controller Charges Battery

Q. A while ago, perhaps in the Nov. or Dec. 2001 issue, you answered a question about the construction of a battery maintenance charger. The circuit is excellent, and I built one myself as a 12-volt motorcycle battery charger. I recently inherited an antique automobile with a six-volt system. Would it be possible to make changes to this circuit so that it can be used as a maintenance charger for a six-volt lead-acid battery?

On a similar note, I would be interested in constructing a controller that senses a low-battery voltage and triggers a solid-state relay, which would switch on the AC power to an off-the-shelf battery charger, like they sell at most auto parts stores. When the battery reaches a full charge, the SSR would turn off and remain that way until another low-voltage condition is detected.

Bob Hempe
via Internet

A. The answer to your first question, described in the Dec. 2001 issue, is to change the 5.6k resistor to 2.2k and substitute the 78L06 with an LM2931Z-5.0. This will properly maintain a six-volt lead-acid or gel-cell battery.

As for your second request, I found it most interesting because it gives me yet another way to exploit the features of the 555 chip. The 555 has two inputs, labeled Trigger (pin 2) and Threshold (pin 6), that toggle the Output (pin 3). When the Trigger goes below 1/3 Vcc, the Output goes high; when the Threshold voltage exceeds 2/3 Vcc, the Output goes low. Typically, a capacitor is inserted between these two inputs and through charging and discharging cycles produces an output waveform.

If the capacitor is removed and a voltage divider is substituted in its place, the 555 becomes a special kind of window voltage comparator (Figure 4). Using the resistance values listed, the relay turns on when the battery needs charging and off when it's fully charged. Unlike a true window comparator — which immediately turns on when the voltage drops below the upper threshold limit — the relay remains off until another low-battery voltage is detected. This circuit can also be used to monitor the level of a water tank or any other device that needs the same on/off profile. Of course, you have to make sure the relay — be it solid-state or mechanical — can handle your load. The relay input is five volts at 200 mA or less.

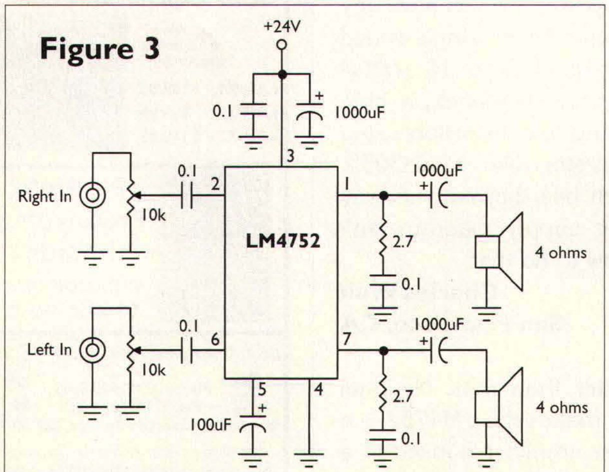
A Call To Arms ... Err, Books

Q. For some time now I have been trying to find software to use with a Dinsmore 1525 compass module interfaced to a microcontroller — like a 16F84 or 16F876 — with an LED display. The 1525 seems to be popular and yet no one seems to have a program for its use. Any ideas?

Ed Cannady
via Internet

A. There was a similar design published in the *PICstart Design Contest Application Brief Notebook (DS30229B)* published in 1993 by Microchip, Inc. Unfortunately, all I can find is a portion of the original publication, which is now available on the *Nuts & Volts* website as **PICstart_1525.PDF**. A call to Microchip revealed that nothing exists but an archive (not currently available) for this publication. But I'm sure there are still some copies out there in the hands of hobbyists. Let's hope this response will turn up one.

Figure 3



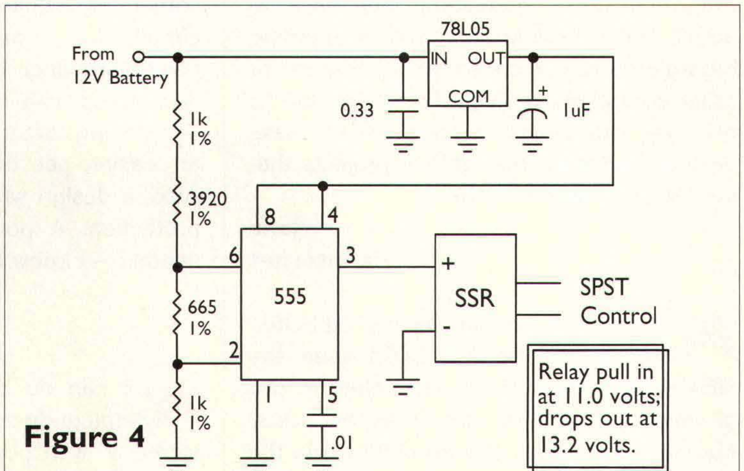


Figure 4

To Power Or Shut Down. Which Is Better?

Q. Are computers better off being left running all the time or shut off each time after use? I would imagine there is a controversy, depending on which camp you're affiliated with.

Lee
via Internet

A. Ten years ago, yes the camps were divided. But with recent advances in semiconductor technology and trends in PC hardware, the two camps now break bread together. That is, in and of itself, the question isn't an issue of concern.

Most PC failures are a result of heat, and not wear and tear on the mechanical devices. In fact, most damage is done when a device is temperature cycled between hot and cold, not when it's running at a constant temperature. So much so that the DoD (Department of Defense) has an environmental test routine for testing accelerate life aging of components by subjecting them to alternating cycles of hot and cold (Mil. Spec. 883B). Considering that the Pentium chip runs hot enough to require its own cooling fan (now that's hot!), you don't have to guess what happens to its internal temperature if it were to be constantly turned on and off.

Heat build-up is further reduced by powering down the PC when it's not in use. If you look carefully, you'll see a section in your BIOS chip (yes, all PCs have one and they can be accessed when power is first applied to the PC) under the heading of Power Management. Here you can tell your system when to shut down devices after specified periods of inactivity. As a rule, the monitor should be turned off after one hour (saving power and wear and tear on the CRT), and the hard disk after about 30 minutes. Don't worry, all it takes to reactivate these devices is a mouse or keyboard input — or a nudge from an Internet interface. For example, my system reduces its power down to 5% of its operating total after about an hour of my stepping away from the keyboard. Less power means less heat, and it's done gradually without the shock of on/off power cycling.

The recent proliferation of fluid-dynamic bearings in disk drives has further reduced the heating and friction problems. Hard disks are amazingly reliable these days, with Mean Time Between Failures (MTBF) of 500,000 to 1,000,000 hours. That means that, on average, half of all drives from the same lot fail after the specified number of hours, 57 years for 500,000 hours, with half of the drives lasting more than that half the MTBF.

On the other hand, if you expect to be away for any period of time (possibly a vacation to Paris, lucky you) or there is a lightning storm looming on the horizon, it would be a good idea to turn the PC off and unplug it to prevent power surges. Don't count on your surge protector to save the day.

Wire Those Walls Before You Plaster

Q. I am in the process of wiring TV and telephone service for my new home and would appreciate the following information. I require TV outlets in six rooms, and knowing there is a dB loss in each coupler, which of the following options would be best? Obtaining a six-outlet coupler or splitting the runs into two lines, one for the top and one for the bottom. I'm thinking of doing the bottom three rooms on one four-output coupler with the forth output going to a second two-outlet coupler. Minimum loss of signal is the main objective, even if it's a little pricey.

Long-Time Subscriber
via Internet

A. That depends on how long the cable runs are and where you split the signal. Like you say, the name of the game is minimal signal loss. Each splice and cable length takes a toll. For practical purposes, the loss of a two-way splitter may be assumed to be 4 dB, a four-way splitter loss can be 7.5 to 8 dB, and an eight-way splitter can be from 11 to 12 dB insertion loss to each port. Add 100 feet of RG59/U cable, and subtract another 9 dB. Table 1, on the next page, lists the loss for various components.

Now, which is the optimum topology for minimal loss? That depends on

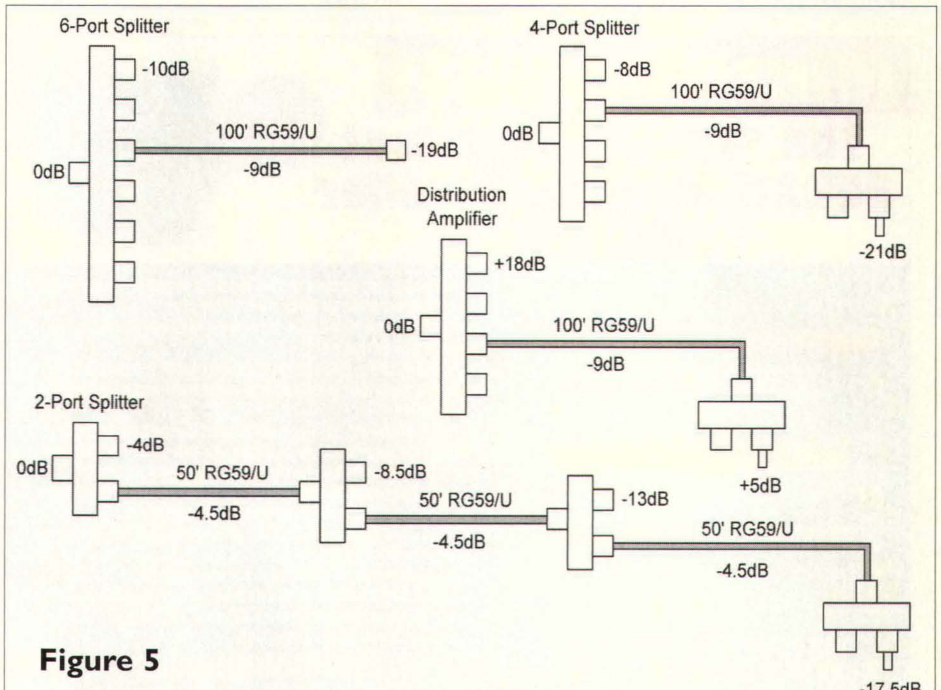


Figure 5

Table I

Device	Signal Loss
Two-port splitter	4 dB
Four-port splitter	8 dB
Six-port splitter	10 dB
Eight-port splitter	12 dB
100 feet RG59/U	9 dB

where in the walls your outlets land. You can pick one or mix the choices in Figure 5. What I'd do is install a CATV distribution amplifier, like the Winegard DA-1018, at the head-in (where the cable comes into your house) and divide the lines down using two-port splitters at the end of the run.

Editor's Choice

Remember "programmed learning" (circa 1960) where you learned at your own pace through branched answers? I recently ran across such a method for learning electronics at Twisted Pair (**www.twysted-pair.com**); click on Free Stuff for an excellent introduction to DC basics. You have a good choice of topics to choose from, including Ohm's and Kirchoff's Laws. I recommend starting with Download Learn Electronics Lesson One. It includes a very thorough hands-on tutorial of electron flow, Ohm's Law, and advanced DC circuit topics. Your answers are checked for accuracy and you're not allowed to advance to the next question until you correctly answer the previous. If you can't answer the question after three tries, they give you the answer. Expect to spend about one hour on the first section alone. (Figure 6.)

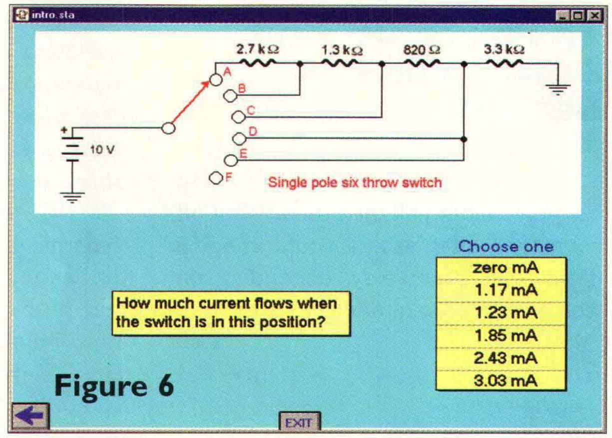


Figure 6

MAILBAG

Dear TJ:

This is in reply to your comment about power line frequency inaccuracy many times in the past. While it's true that the short time accuracy of the power line frequency is as bad as you say and clocks that are based on it can be off by several seconds or more at any given time, this is not the whole story. The fact is, the long term accuracy of the power line frequency is dead on. Over a period of months and years, you just can't get a more accurate frequency source. Not crystals, not crystals in temperature-controlled ovens, not even atomic clocks ... nothing.

Why? Because the power companies monitor WWV which is adjusted by monitoring the heavens. They adjust the frequency/phase of their generators to bring the clocks back into sync with WWV and hence, with the universe. They may be off by seconds or even tens of seconds in the short run, but in the long run, they are dead accurate.

I know that power-line 60 Hz may not be suitable for all purposes, the choice should be made with all the facts and not a distorted view. If the reader wants long-time clock accuracy, you can't do any better. For short term stability go crystal; for more accuracy than 0.4% try a PLL.

E. Paul Alciatore, III
Chief Engineer
hawthorne direct, inc.
Fairfield, IA

Cool Web Sites

A problem I hear often about Windows Internet Explorer (IE) is its inability to remember that most people want it to launch as a maximized window. The best solution? IE New Window Maximizer 2.2, a free utility that does just that, as well as handling a few other things like stopping pop-up windows. You can download a copy at:

www.jiisoft.com/iemaximizer/index.htm

Need to find a schematic or manual for a piece of electronic equipment with no model number or manufacturer tag? Every item that emits a radio frequency can be traced back to its source via its FCC ID number.

www.fcc.gov/oet/fccid

"Where It Is and How to Get It"

Robotics Resources

Hunting the Surplus Electronics Store

Surplus is a loaded word. To some, it means junk that just fills up the garage, like musty canvas tents, or funky fold-up shovels once used by the Army in the 1950s. To the true robot buff, surplus has a totally different meaning: affordable components to help stretch the robot-building dollar.

Surplus just means that the original maker or buyer of the goods doesn't need it any more. Surplus is simply excess stock for resale. In the case of electronics, surplus seldom means "used" as it may for other surplus components, such as motors or mechanical devices. Except for special components — like older amateur radio gear — surplus electronics are typically brand new, and much of it may still be in active manufacture.

The main benefit of shopping the surplus electronics retailer is cost: even for new components, prices are generally lower than from general electronics retailers. On the downside, selection may be limited to whatever components the store was able to purchase. Don't expect every value and size of resistor or capacitor.

This month, we look at almost three dozen electronics retailers that regularly stock surplus components commonly used in amateur robot building. Today, many surplus stores are local businesses that also sell on the Internet, either through a shopping cart or through eBay. When the resource offers online sales it is noted, along with the availability of a shopping cart or some other "online catalog."

This time around, we'll concentrate on surplus resources within the United States only, and cover Canada, the UK, and other countries in a future installment. And for the sake of space, we'll skip the surplus companies that primarily deal with used PC parts, and concentrate just on electronic and electromechanical components of use to robot builders.

A-2-Z Solutions, Inc.

P.O. Box 740756
Boynton Beach, FL 33474-0756
www.a2z-solutions.com

New and surplus electronics. Mostly computer equipment (PCs, monitors, scanners, and so forth). Online sales with web catalog.

AE Associates, Inc.

7733 Densmore Ave. #5
Van Nuys, CA 91406
www.ae4electronicparts.com

New and used electronics, including switches, connectors, electronic components (resistors, capacitors, diodes, transistors, etc.), and test equipment. Searchable database. Also sells a small number of compact black & white and color video cameras. Local store in Van Nuys, CA; online sales with web catalog.

All Electronics Corp.

P.O. Box 567
Van Nuys, CA 91408-0567
www.allcorp.com

All Electronics is one of the primary sources in the US for new and used robotics components. Prices and selection are good. Walk-in stores in the Los Angeles area. Product line includes motors, switches, discrete components, semiconductors, LEDs, infrared and CdS sensors, batteries, LCDs, kits, and much more. Specification sheets for many products are available at the web site. Online store, web catalog, and printed catalog.

Alltronics

P.O. Box 730
Morgan Hill, CA 95038-0730
www.alltronics.com

New and surplus merchandise. Among their product line useful in robotics are DC and stepper motors, stepper motor controllers, power MOSFETs, small CCD video cameras, and tools. Online sales with web catalog.

American Science & Surplus

3605 Howard St.
Skokie, IL 60076
www.sciplus.com

AS&S sells surplus of all types, including some you'd normally find in an Army/Navy surplus store. But they also carry motors, gears, batteries, switches, and some electronics.

APEX Electronics

8909 San Fernando Rd.
Sun Valley, CA 91352
www.apexelectronic.com

Military and industrial surplus, with a major emphasis on wire of all types and sizes. Huge selection, but the retail store is not well organized, and little is priced. Limited online sales (only some components listed on the site).

Apex Jr.

3045 Orange Ave.
La Crescenta, CA 91214
www.apexjr.com

Surplus electronics and mechanicals. General electronics, transformers, and "movie props." Online store with web catalog.

Ax-Man Surplus

1639 University Ave.
St. Paul, MN 55104

www.ax-man.com
Local (St. Paul, Fridley, and St. Louis Park, MN) electronic and mechanical surplus.

B.G. Micro

555 N. 5th St., Suite #125
Garland, TX 75040
www.bgmicro.com

A haven for the electronics tinkerer and robotics enthusiast. Much of the stock is surplus, so it comes and goes, but while it's being offered, it has a good price attached to it. Online sales through web catalog, printed catalog available.

BCD Electro, Inc.

2525 West Commerce
Dallas, TX 75212
www.bcdelectro.com

Surplus electronics: active and passive electronics, motors, relays, switches, etc. Online sales.

BMI Surplus

P.O. Box 652
Hanover, MA 02339
www.bmius.com

Electronic surplus, much of it high-end industrial or scientific; opticals, laser. Online sales with web catalog.

Boeing Surplus Store

20651 84th Ave. S.
Kent, WA 98032
www.boeing.com/assocproducts/surplus

All sorts of surplus, from small plastic parts to large machine tools — but no aircraft parts. My guess is that Boeing buys this stuff, puts it in a warehouse somewhere for a few years, then sells it at their surplus store at great prices! Local only in Seattle, WA with a satellite office in Los Angeles, CA.

Brigar Electronics

7-9 Alice St.
Binghampton, NY 13904
brigarelectronics.com

Handy selection of electronic components, including unique sensors, construction hardware, and motors, along with the usual transistors, resistors, etc. Online sales with web catalog.

C & H Sales

2176 E. Colorado Blvd.
Pasadena, CA 91107
www.candhsales.com

C & H is primarily a source for mechanical surplus, but they also stock various passive components, as well as switches, relays, and motors. Online sales through web catalog, printed catalog, and walk-in store in Pasadena, CA.

CTR Surplus

202 West Livingston Ave.
Crestline, OH 44827
www.ctrsurplus.com

Surplus electrical, including motors, test equipment, and power supplies. Online sales with web catalog.

EIO.com

P.O. Box 3148
Redondo Beach, CA 90277
www.eio.com

Surplus sales of all major electronics components, plus links and resources. Online sales with web catalog.

Electro Mavin

2985 E. Harcourt St.
Compton, CA 90221
www.mavin.com

Electronic components, motors, batteries, optics, and test equipment. Online sales with web catalog; retail store in Los Angeles area.

Electronic Dimensions

424 Puyallup Ave.
Tacoma, WA 98421
www.el-dim.com

Military and industrial surplus, electronics, radio receivers, transmitters and parts, electron tubes, test equipment, and ham gear. Retail store in Washington state, and online sales with web catalog.

Electronic Goldmine

P.O. Box 5408
Scottsdale, AZ 85261
www.goldmine-elec.com

New and used electronic components (LEDs, potentiometers, resistors, heatsinks, transistors, etc.), robot items, electronic project kits, and more. Online sales with web catalog.

Electronic Surplus, Inc.

5363 Broadway Ave.
Cleveland, OH 44127
www.electronicsurplus.com

Wide selection of test equipment and electronics parts.

Electronics Plus

10302 Southard Dr.
Beltsville, MD 20705
www.electronics-plus.com

Product lines include batteries and battery accessories; cable and wire; capacitors and resistors; chemicals; circuit boards and accessories; coils, chokes, inductors, and more. Local retail store and online sales with web catalog.

Electronix Express

365 Blair Rd.
Avenel, NJ 07001
www.elexp.com

New and surplus electronics, including passive components, motors, relays, and more. Online sales with web catalog.

Excess Solutions

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You've probably bought mail order before, so you know the drill. But for a reminder's sake, here's a list of do's and don'ts when conducting business by mail.

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Understand exactly what you are buying, when delivery will be made, and how much you're paying before sending any money. Sounds simple enough, but it's easy to forget the small stuff when you're excited about finding goodies for your robot.

Favor those companies that provide a mailing address and a working phone number for voice contact (not just fax). Sellers without one or the other aren't necessarily crooks, but lack of contact information just makes it harder to get hold of someone should there be a problem.

Be wary of companies that advertise by sending unsolicited "spam" via email. Spam is basically free to send, so everyone can do it — including the scamsters.

Verify shipping charges, handling charges, and service fees before finalizing the order. These costs can significantly add to the price, especially for small orders.

Check out the company before sending them a significant order ("significant" is up to you; it might be anything over $500.00, or it might be anything over $35.00). Check for a poor rating with the Better Business Bureau (or similar institution for those outside the US) in the company's home town; in the appropriate newsgroups; or in online chatrooms or bulletin boards.

Determine added costs for duty, taxes, and shipping when buying internationally.

Carefully examine your monthly credit card statement for improper charges.

Don't:

Give your credit card number via email, or on a web page order form, unless you know the communications link is secure.

Buy from a source unless you feel very comfortable you can trust your money with them.

Use a credit card to pay for goods from a company you have not yet dealt with, sending a check or money order is just as easy. This limits the exposure of your credit card accounts to possible Internet fraud.

Send money to foreign companies unless you're positive they are safe bets. While you're checking them out, be sure they will ship to your country.

Should you have trouble with a mail order merchant (and you or the business is in the US), the following two organizations might be able to help you resolve the matter.

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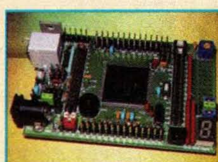
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by James L. Antonakos

Electronic Theories and Applications From A to Z

Let's Get Technical

Inside Protected Mode — Part I
Memory Segmentation and Paging

This month, I begin a two-part examination of protected-mode architecture — the powerful behind-the-scenes arbiter of all that goes on behind the Windows desktop or Linux kernel, deep inside the Pentium (or equivalent) CPU. This topic is a mixture of hardware and software, each affecting the other.

Introduction

The architecture of the Pentium's protected mode is significantly different from that of real mode. Real-mode operation refers to the original 8086 (or 8088) architecture, which provided four 16-bit segment registers (CS, DS, ES, and SS) and a 20-bit address bus. In real mode, addresses are generated by shifting 16-bit segment registers to the left, and adding a 16-bit offset to create a 20-bit physical address. The 20-bit address supports a 1MB real-mode addressing space. As we will see, in protected-mode, memory addresses are generated in a totally different way.

Segment registers are now called segment selectors, and point to a structure called a segment descriptor. The segment descriptor contains addressing and control information which is used to control how a 32-bit linear address is generated. These addresses may then be further translated by a paging mechanism before emerging as a physical address somewhere in the Pentium's 4GB addressing space. Beginning with the 80386 CPU, the features of protected mode enabled operating system designers to manage and protect memory and user tasks, using built-in protected-mode hardware and software. A number of additional registers are available in protected mode. These registers are shown in Figure 1. The five control registers in Figure 1(a) control how memory and cache are used and how the FPU (Floating Point Unit) is handled, and provide information on the current execution state.

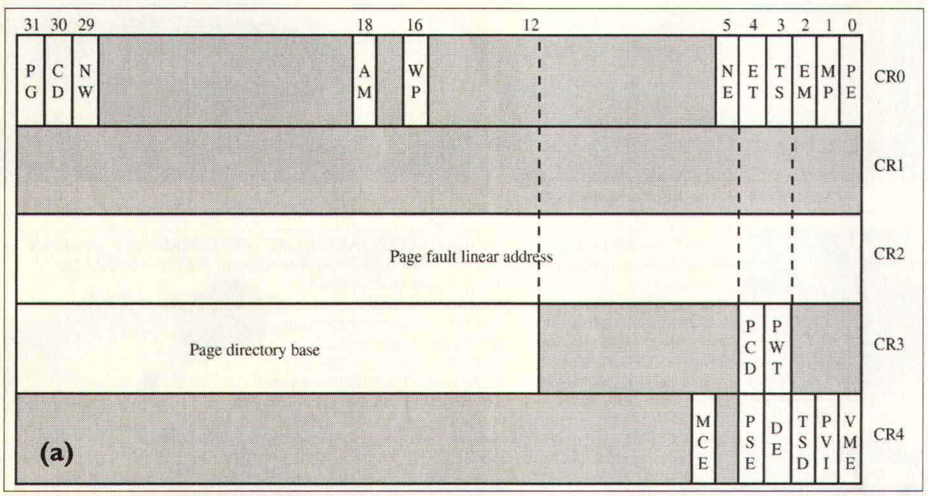
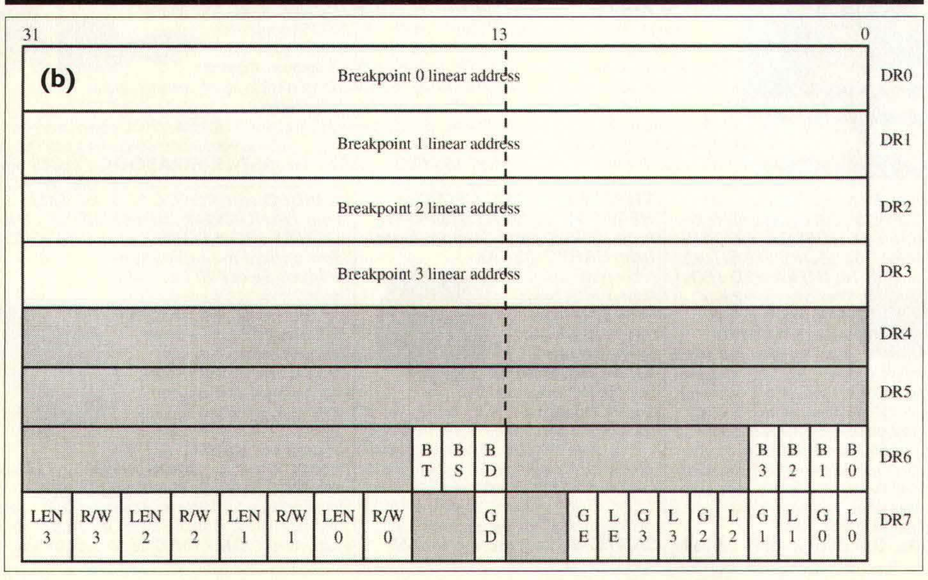


Figure 1: Additional protected-mode registers: **(a)** control registers, **(b)** debug registers.



CR0 contains many important control and status bits. Their functions are as follows:

PG: Paging. Enables paging when set.
CD: Cache Disable. Disables cache writes when set.
NW: Not Writethrough. Disables cache writethrough operations when set.
AM: Alignment Mask. Allows alignment checking when set.
WP: Write Protect. Enforces supervisor-level write protection when set.
NE: Numeric Error. Allows floating-

point errors to be reported when set.

ET: Extension Type. Reserved.

TS: Task Switch. Set when a task switch occurs.

EM: Emulation. Indicates the presence of a coprocessor. Should be zero on the Pentium, which has an internal FPU.

MP: Monitor Coprocessor. Must be set to run 80286 and 80386 programs on the Pentium.

CR2: Contains the 32-bit linear address that generated the most recent page fault.

CR3: Contains the base address of the current Page Directory, which is used to support paging.

CR4: Has six bits whose operation is as follows:

VME: Virtual-8086 Mode Extensions. When set, enables emulation of a virtual interrupt flag.

PVI: Protected Mode Virtual Interrupts. When set, allows a virtual interrupt flag to be maintained in protected mode.

TSD: Time Stamp Disable. Used to make the RDTSC instruction privileged.

DE: Debugging Extensions. Enables I/O breakpoints when set.

PSE: Allows 4MB pages when set.

MCE: Enables the machine check exception.

Figure 1(b) shows the eight debug registers. These registers are used to support program debugging by indicating the address at which a program breakpoint was generated, as well as the size of the breakpoint data or instruction, whether it was a read or write request, and what kind of bus cycle (instruction fetch, data, or I/O access) to generate breakpoints on. Both control and debug registers may be loaded or saved using the MOV instruction.

Additional protected-mode registers are used to support interrupts and tasks, and these will be covered as well, including the GDTR (Global Descriptor Table Register), LDTR (Local Descriptor Table Register), IDTR (Interrupt Descriptor Table Register), and TR (Task Register). Privileged instructions that operate on these new registers are present in protected mode, and these will be examined also. Briefly, these new instructions are as follows:

ARPL: Adjust requested privilege level
CLTS: Clear task switched flag
CPUID: CPU identification
LAR: Load access rights
LGDT: Load global descriptor table register
LIDT: Load interrupt descriptor table register
LLDT: Load local descriptor table register
LMSW: Load machine status word
LSL: Load segment limit
LTR: Load task register
MOV: Move data to/from control register
RDTSC: Read from time stamp counter
SGDT: Store global descriptor table register
SIDT: Store interrupt descriptor table register
SLDT: Store local descriptor table register
SMSW: Store machine status word
STR: Store task register
VERR: Verify segment for reading
VERW: Verify segment for writing

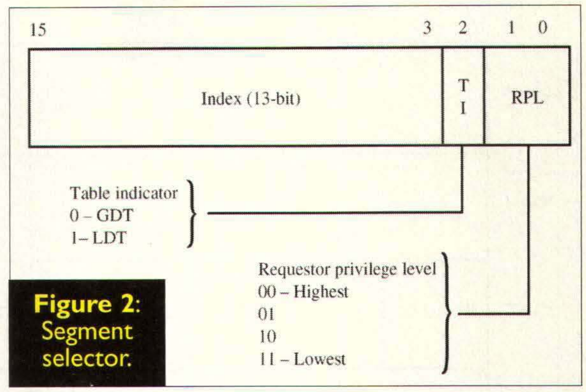


Figure 2: Segment selector.

Segmentation

Segmented memory is utilized by protected mode to allow tasks to have their own separate memory spaces, which are protected from access by other tasks. In this section, we will examine the operation of segmented memory.

Selectors — As previously mentioned, the segment registers we are familiar with from real mode have a different function in protected mode. Figure 2 shows the format of a segment selector.

Segment selectors contain a 13-bit index field that is used to select one of 8,192 segment descriptors that reside either in the global descriptor table (GDT) or the local descriptor table (LDT). There is only one GDT in protected mode. Protected-mode tasks, however, may each have their own LDT. The TI bit in the segment selector picks the appropriate descriptor table during translation. The GDT is located in memory through use of the GDTR. The GDTR is initialized with the LGDT (load global descriptor table register) instruction. LGDT loads six bytes of data from a source memory operand into the GDTR.

Local descriptor tables are referenced through the LDTR, which is initialized through use of the LLDT (load local descriptor table register) instruction. LLDT requires a word-size register or memory operand, which represents the index of the LDT in the GDT. To obtain a copy of the current GDTR or LDTR, use the SGDT (store global descriptor table register) or SLDT (store local descriptor table register) instructions. SGDT requires a six-byte destination operand in memory. The destination for SLDT is a word-size register or memory operand.

Two requestor privilege level (RPL) bits are used in protection checks to determine if access to the segment is allowed. Selectors may be loaded into any of the six segment registers (CS, DS, ES, FS, GS, and SS). A selector that has an index value of zero and points to the GDT is called a null selector. This selector value is reserved to provide a method of initializing segment registers, since any access using a null selector generates an exception.

Segment Descriptors — A selector points to one of 8,192 segment descriptors stored in the GDT or LDT. The structure of a segment descriptor is shown in Figure 3. The segment descriptor contains a 32-bit base address that specifies the beginning of the segment of memory controlled by

Table 1: Segment descriptor types.

Type	Description	
0	Read-only	*Data Descriptors*
1	Read-only, accessed	
2	Read/write	
3	Read/write, accessed	
4	Read-only, expand down	
5	Read-only, expand down, accessed	
6	Read/write, expand down	
7	Read/write, expand down, accessed	
8	Execute-only	*Code Descriptors*
9	Execute-only, accessed	
A	Execute/read	
B	Execute/read, accessed	
C	Execute-only, conforming	
D	Execute-only, conforming, accessed	
E	Execute/read-only, conforming	
F	Execute/read-only, conforming, accessed	

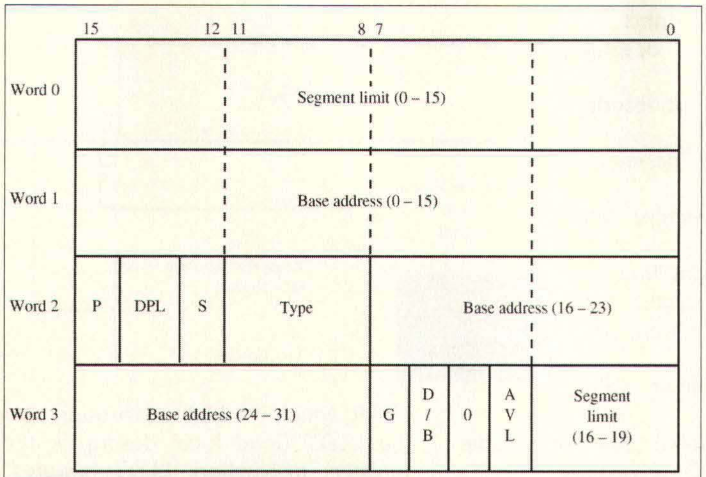


Figure 3: Segment descriptor format.

Type	Description
0	Reserved
1	Available 16-bit TSS
2	LDT
3	Busy 16-bit TSS
4	16-bit call gate
5	Task gate
6	16-bit interrupt gate
7	16-bit trap gate
8	Reserved
9	Available 32-bit TSS
A	Reserved
B	Busy 32-bit TSS
C	32-bit call gate
D	Reserved
E	32-bit interrupt gate
F	32-bit trap gate

Table 2: System segment descriptor types.

the descriptor. The size of the segment is indicated by a 20-bit limit field and the state of the G (granularity) bit. When G is clear, the limit bits represent a segment size up to 4KB.

Any attempt to access a memory location outside the limit generates an exception.

When the granularity bit is set, the limit bits represent the number of 4KB pages contained in the segment. This allows the size of a segment to be from 4KB to 4GB!

Two descriptor privilege level (DPL) bits specify the privilege level required to access the segment. An attempt by a less privileged task to use the segment results in an exception. The remaining bits are defined as follows:

P: Indicates whether the segment is present in memory. A segment-not-present exception is generated if this bit is clear when the segment descriptor is accessed.

S: When set, indicates that the segment is a system segment. When clear, the s segment is a code or data segment.

D/B: For code segments, D/B controls the default operand and address size (16 bits when D/B is clear versus 32 bits when set). For data segments, D/B controls how the stack is manipulated (via SP or ESP with 16- or 32-bit pushes/pops).

AVL: Available to the programmer.

Type: This four-bit field determines what kind of segment descriptor is being used.

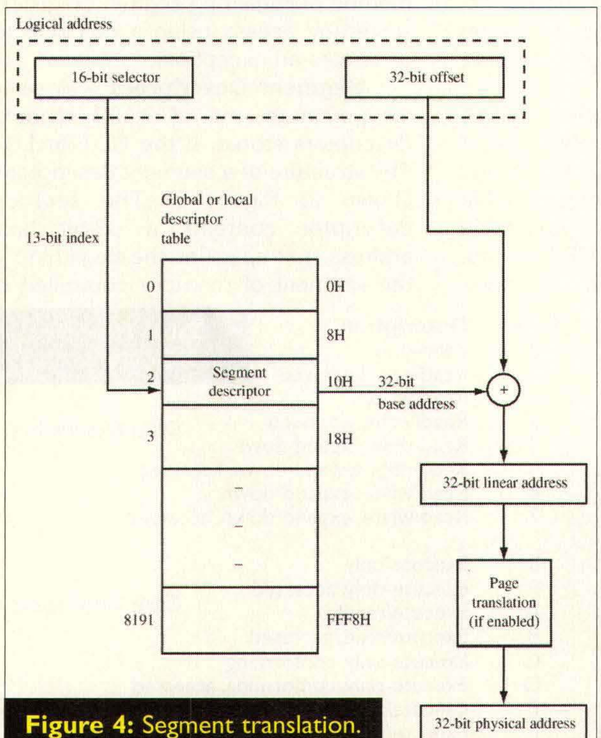


Figure 4: Segment translation.

Table 1 shows the various types of segment descriptors that may be used by applications. Table 2 shows the different system segments that are available.

Generating a Linear Address — When a valid descriptor is in place in the GDT or LDT, the linear address associated with it is generated by the process shown in Figure 4. The 13-bit index from the segment selector points to a segment descriptor in the GDT or LDT. The 32-bit base address from the segment is added to the 32-bit offset to create the linear address. This address is compared with the limit information to check for illegal memory references.

The segment limit of a selector can be examined with the LSL (load segment limit) instruction. The segment limit of the segment specified by the source operand is loaded into a destination register. If paging is not used, the 32-bit linear address is the same as the 32-bit physical address output on the address lines. Otherwise, the paging hardware converts the linear address into a physical address.

Privilege Levels — The RPL and DPL bits found in the segment selector and descriptor are used to perform protection checks each time an address is generated. These protection checks are based on a four-level privilege hierarchy, with level 0 being the highest level of privilege, and level 3 the lowest. Programs execute with a particular level of privilege, and therefore make memory requests (and other types of requests, such as interrupt and subroutine re-quests, or task switches) based on their privilege level. The privilege level of the currently-executing program is called the current privilege level (CPL). The lower two bits of the CS register specify the CPL of the program. The CPL is compared with the RPL and DPL during address generation to enforce protection.

In general, a less privileged program may not access higher privileged segments. Intel refers to the four privilege levels as rings of protection. As shown in Figure 5, a typical operating system might use privilege level 0 (the highest) for private OS functions, level 1 for OS services available to applications, level 2 for device drivers, and level 3 for application programs. This allows the operating system to have control over what code and data structures are available to software running on the system. Any protection violation will cause an exception that may be serviced by the operating system. So, programs will not be able to get away with illegal memory references (over-writing important operating system data tables) or function calls (like calling a function that changes privilege levels).A number of instructions are provided to manipulate and examine protections. These are:

ARPL: Adjust requested privilege level
LAR: Load access rights
VERR: Verify segment for reading
VERW: Verify segment for writing

ARPL is used to adjust the privilege level of a selector by comparing privilege levels of source and destination operands. LAR loads a copy of the access rights of a selector containing a source operand into a destination register. VERR and VERW both compare the current privilege level with that of the source operand selector. If read or write access is allowed, the zero flag is set.

Paging

The Pentium supports translation of virtual (linear) addresses into physical addresses through the use of special tables that map portions of the virtual address into actual physical memory locations. Figure 6 illustrates the general process.

Physical memory is divided into fixed-size page frames of 4KB each; 32-bit virtual (linear) addresses generated by a running task select entries in the systems page directory and page table, which translate the upper 20 bits of the virtual address into the actual physical address where a page frame is located. The lower 12 bits of the virtual address are not translated and point to one of 4,096 byte locations within a page frame. Page translation allows the physical memory used by a system to be much smaller than the linear addressing space. For instance, the Pentium's 4GB linear addressing space may be mapped to a physical memory of only 128MB. This does not pose a problem – as evidenced by Windows and Linux, which run quite nicely with 128MB of RAM.

As Figure 6 shows, the pages used by a program do not need to be stored consecutively. A program's code and data may be spread out all over physical memory, and even moved around (with help from the hard disk) while the program is executing! This helps to explain why the linear addresses are also called virtual addresses, since they have no relation to the actual physical memory address used, except for the lower 12 bits. Paging is enabled when the PG bit in CR0 is set. This is a requirement for running multiple tasks in virtual-8086 mode. In addition, many operating systems employ a memory management technique called demand paging, which requires the kind of address translation described here.

Page Directories and Page Tables – Figure 7 shows how a 32-bit virtual address is translated into a physical address. The upper 10 bits of the virtual address select one of 1,024 entries in the page directory. The base address of the page directory is stored in the page directory base register (PDBR). Each entry in the page directory is four bytes wide and contains the base address of a page table. The next 10 bits from the virtual address select one of 1,024 entries in the page table pointed to by the page directory entry. This entry is also four bytes wide and contains the base address of the actual physical memory page frame. This address is combined with the lower 12 bits of the virtual address to access the desired location in memory.

Note that the page directory and page table are themselves also 4KB page frames stored in memory. Let us examine an actual virtual-to-physical address translation. Figure 8 outlines the translation process. The virtual address 801C3400H is broken up into three parts. The upper 10 bits contain the value of 200H (when reinterpreted). This is the offset of the page directory entry. The PDE contains the base address 000E4000H. This is the base address of the page table. The next 10 bits of the virtual address have a value of 1C3H, which becomes the offset into the page table. The address stored in the PTE (00028000H) is the base address of the physical memory page frame. This address is combined with the lower 12 bits of the virtual address (400H), giving a physical address of 00028400H.

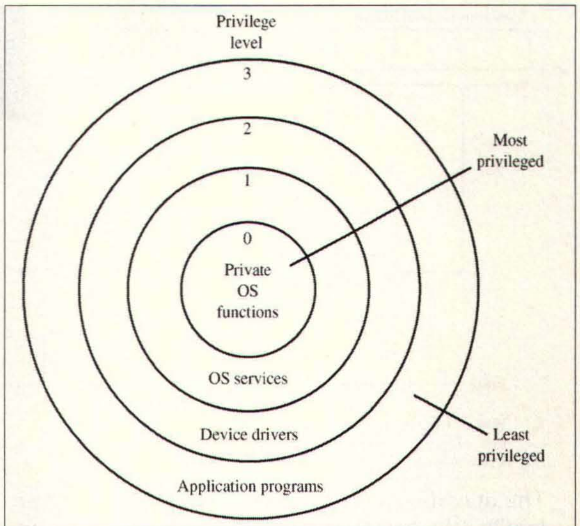


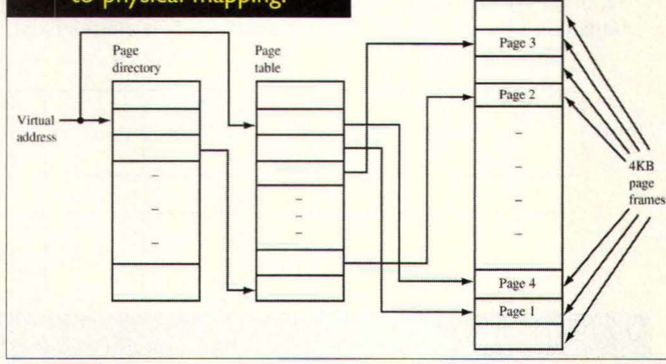
Figure 5: Rings of protection.

Translation Lookaside Buffers – Since the page directory and page table are 4KB pages themselves, it would be very inefficient to have to access them every time an address requires translation, since two memory reads are needed to read the entries from each table.

To improve performance, the internal instruction and data caches of the Pentium contain small, special caches called translation lookaside buffers (TLBs) that automatically translate the upper 20 bits of the virtual address into the upper 20 physical memory address bits. The TLBs are needed because the cache must be accessed with physical, not virtual, addresses.

The TLB can translate the virtual address and access the cache with it in a single clock cycle. Since the TLBs are small, they contain only the addresses of a few of the most recently-used pages. If the required translation information is not found in the TLB, the processor accesses the page directory and page table entries stored in RAM.

Figure 6: Virtual (linear) to physical mapping.



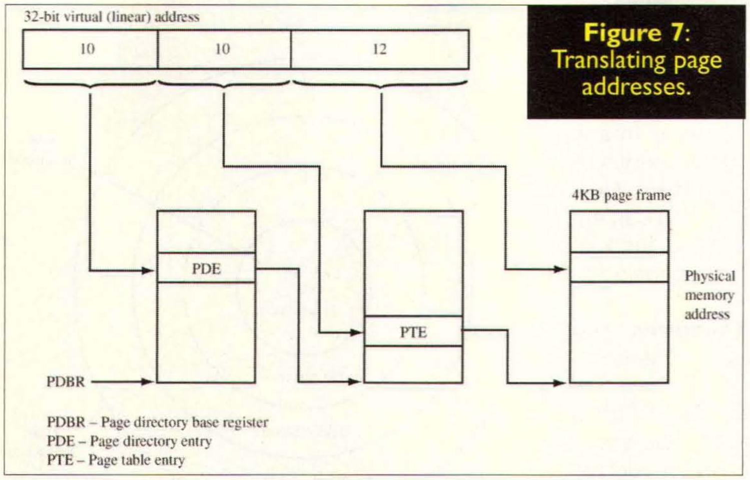


Figure 7: Translating page addresses.

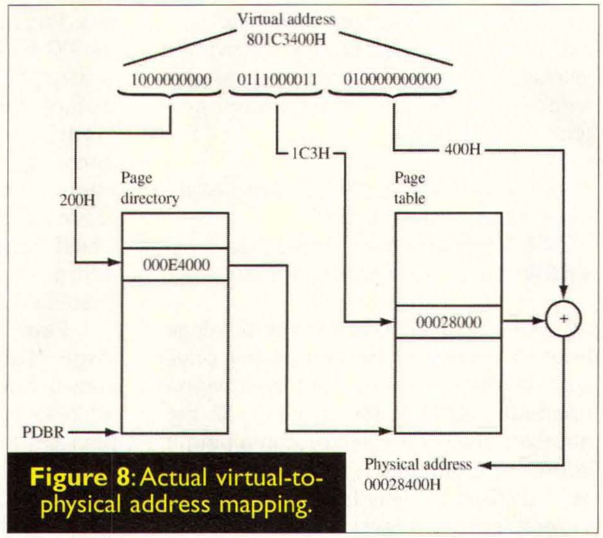


Figure 8: Actual virtual-to-physical address mapping.

The operating system is responsible for loading the new translation information into the TLB. Prior to doing this, it may be necessary to invalidate the contents of the TLBs, since they may contain out-of-date information. The INVLPG (invalidate TLB entry) instruction is provided for this purpose, and may only be executed in protected mode.

Page Directory Entry and Page Table Entry Formats — Figure 9 indicates the formats of page directory and page table entries. The upper 20 bits of each entry specify the base address of a page frame. In the PDE, this address is the base address of a page table. In the PTE, this address is the base address of the physical memory page frame. Three bits are available for the programmer to use for any purpose, such as counting the number of times the entry is accessed. The remaining bits in each entry are defined as follows:

D: Dirty. This bit is set if a write has been performed to the page pointed to by the PTE. Dirty bits are used to determine if the page should be written back to the hard disk when the page is swapped out (to make room for a new page coming in).

A: Accessed. This bit is set if a read or write was performed to the page selected by the PDE and PTE. This bit is used by the operating system to help choose a victim page to swap out when all pages are in use and a new page must be loaded into RAM. A page that has been accessed is less likely to be swapped out than a page that has not been accessed.

PCD: Cache Disable. This bit determines whether the current memory access is cached.

PWT: Writethrough. This bit enables writethrough operations between the cache and memory.

U: User. This bit is used when performing protection checks on the current memory address.

W: Writeable. This bit determines whether the page may be written to and is also used in protection checks.

P: Present. This bit indicates whether the page is actually stored in memory.

In a demand-paging system, when a new page is needed, one of two conditions may be true:

- There is a free page frame available.
- No page frames are available.

If a page frame is available, the new page is simply copied into memory at the appropriate address, the TLBs are updated, and the P-bit is set to indicate that the page is in memory. If no free pages exist, a victim page must be chosen to make room for the new page. The P-bit of the victim's PTE is cleared, to show that the page has been swapped out. The page may be copied back to the hard disk (as required by the dirty bit) before the new page is read in.

The Pentium uses the P-bit to generate a page fault when attempting to access a page that is not in memory. One characteristic of a demand-paging system is that pages are only brought into memory when needed. Page faults are used to load a page into memory the first time it is needed, and to reload it if it has been swapped out.

It is interesting to note that, using demand-paged virtual memory management, all or part of many different programs may be stored in many different locations in physical memory. Page faults are used to bring in other parts (pages) of the programs, as needed. Performance depends on how many pages a program is allowed to have in memory at one time.

	31–12	11–9	8	7	6	5	4	3	2	1	0
PDE (a)	Page frame address (12 – 31)	Avail.	0	0	0	A	PCD	PWT	U	W	P
PTE (b)	Page frame address (12 – 31)	Avail.	0	0	D	A	PCD	PWT	U	W	P

Figure 9: Format of **(a)** page directory entry; **(b)** page table entry.

More to Come

In Part 2, I'll examine some additional protected-mode features, including protection, multitasking, interrupts, protected-mode input/output operations, and Virtual-8086 mode. An actual protected-mode assembly language program will also be presented. **NV**

You may reach James Antonakos at **607-778-5122** or **antonakos_j@sunybroome.edu** or visit his web site at **www.sunybroome.edu/~antonakos_j**.

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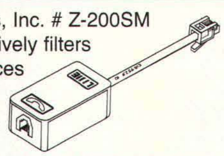

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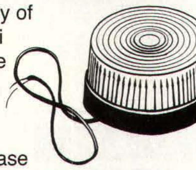

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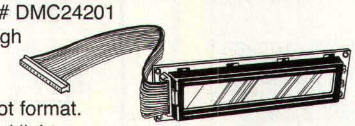

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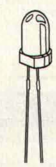

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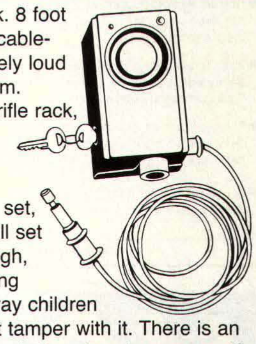

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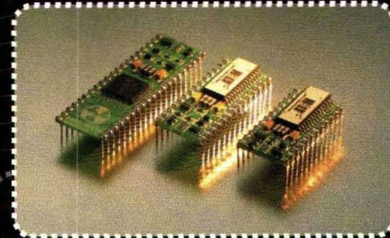

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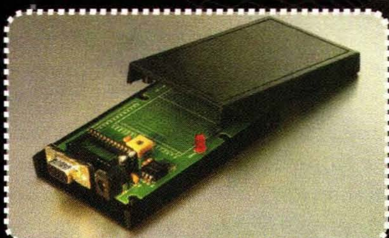

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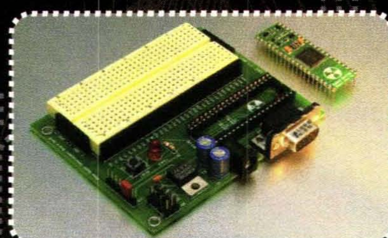

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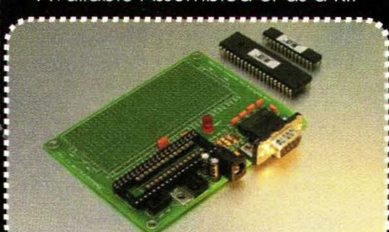

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Texas Instruments and *Nuts & Volts* 2002 MSP430 Ultra-low Power Flash MCU Design Contest 2nd Place Winner

Ultra-low Power Radiation Monitor

by Henry Chan

Have you ever wondered how much radiation the stars are showering on earth? Worried about radon contamination in your environment? Or just curious about radiation in general? This article describes a simple radiation detector based on Texas Instrument's MSP430F1121 ultra-low power microcontroller.

Radiation 101

Radioactive decay is the natural process of conversion from one radioactive isotope into another. Decay causes four different types of radioactive emission: alpha, beta, gamma, and neutron. Depending on the isotope, different types of radiation will be emitted.

Alpha particles consist of two protons and two neutrons, carrying a charge of +2. Beta particles are electrons with a charge of -1. Neutrons have no charge. Gamma rays are high-energy electromagnetic waves at the upper end of the electromagnetic spectrum. These types of radiation are known as ionizing radiation. You may be surprised to know that some common household items can emit radiation. They include ionizing smoke detectors (Americium-241), old luminescent radium clock dials, lantern mantles with traces of thorium, and radon gas.

There are several main types of radiation detectors in use today: gas ionization, solid-state, and scintillation detectors. Gas ionization detectors such as the Geiger Muller (GM) tube rely on the principle that ionizing radiation causes a gas to reach a plasma state, becoming momentarily conductive. A GM tube, basically, consists of a thin wire suspended in the middle of a foil cylinder, enclosed in a halogen quenched tube. The tube is charged to a voltage just below the ionization voltage of the gas inside, usually about 600 volts. Radioactive particles entering the tube ionize some of the gas molecules, resulting in charged ions. The electric field set up by the high voltage accelerates the electrons through the gas and, in the process, bump into other molecules, thus ionizing them as well. The chain-reaction results in a very large response for a small incoming particle, allowing easy detection. This ease of detection makes GM tubes a popular option.

Other detectors include solid-state detectors which can use PIN photodiodes to detect radiation, converting the energy from the radiation directly to electron movement. Scintillation detectors use light-emitting materials when exposed to radiation, along with a method to measure the emitted light. Such detectors can consist of a scintillation crystal coupled to the input of a photomultiplier tube (PMT) or photodiode. The output can be used to drive a counter, or may be integrated to produce a voltage proportional to the sensed radiation levels.

Front-end Design

The detector used in this device can be anything that provides a pulse for every detected radiation event. The front-end consists of a detector based on one of the "Ideas for Design," submitted by Peter Lay, in the March 18, 2002 issue of *Electronic Design*. A cheap neon bulb was used in place of a GM tube in a simple Geiger counter circuit. The design was also featured in the Jan. 2003 issue of *Nuts & Volts*, where 10 nine-volt batteries were substituted for the AC power-line supply. (Visit **www.elecdesign.com** and look under "Ideas for Design.") The detector is insensitive to alpha particles since they are larger and cannot penetrate the glass. The bulb is good for detecting beta particles and gamma rays, though the sensitivity will depend on your bulb's construction.

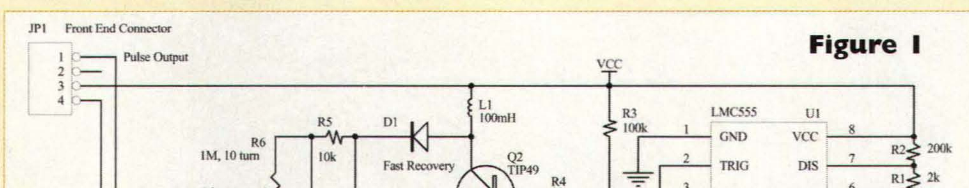


Figure 1

In the circuit, the voltage to the neon bulb is adjusted to a level just below the point of ionization. A current-limiting resistor is selected such that it is not enough to sustain current flow, causing the light to extinguish after ionization. A particle of incoming radiation causes ionization of the gas, resulting in a brief pulse of current. These pulses can then be counted or fed to a speaker for audible monitoring.

I designed a low-current inverter to use in place of the batteries to generate the required voltage using only a 1.5-volt battery as the power source. (See Figure 1.) The power supply is based on a CMOS 555 timer, which draws very little quiescent current at operating voltages down to one volt. The timer generates a squarewave which charges and discharges an inductor. The voltage spikes generated by inductor L1 from interruption of current are directed via a fast-recovery diode D1 to a 0.1 uF capacitor to obtain high-voltage DC. Use of a standard, run-of-the-mill, non-fast-recovery diode will result in significantly reduced output voltage. Please note that the transistor must be able to withstand the high voltage produced by the inductor without being destroyed, which the TIP49 can do. The current flowing through the zener diode regulator also flows through a transistor, which is used to temporarily disable the inverter when the voltage is high enough. This saves power and allows the inverter to be used at higher voltages while drawing less current.

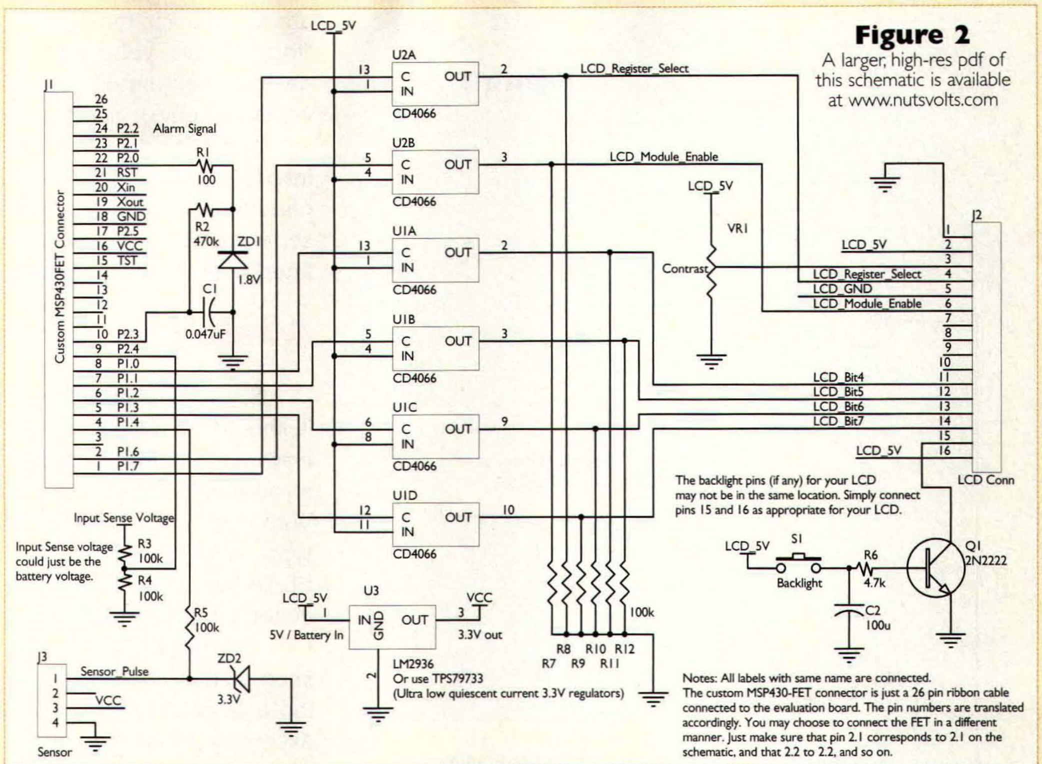


Figure 2

A larger, high-res pdf of this schematic is available at www.nutsvolts.com

All components in the detector circuit labeled with an asterisk (*) need to be customized for your particular bulb. The given values will work with RadioShack part number 272-1100B. Current-limiting resistor R8 in the detector circuit needs to be chosen such that the neon bulb extinguishes immediately after ionization, allowing the detector to reset itself. Regulating diode D2 is a 100-volt zener diode, but depending on your neon bulb, may need to be changed. I have seen bulbs that light at 75 volts to bulbs that don't light even at 100. Capacitor C5 allows the bulb to conduct with more current, giving a nice output pulse. The output is taken across the 33k resistor, and can be relatively high in amplitude. A 3.3-volt zener diode across this resistor will clamp the output signal down to a safe level for logic circuitry.

Microcontroller and Firmware

The heart of the "counter" for the radiation monitor is the ultra-low power MSP430F1121 from Texas Instruments. This microcontroller has multiple sleep modes that can reduce power consumption from 160 uA (1 MHz, run mode) down to 0.1 uA (off mode, RAM retention) making it ideal for battery-powered applications.

Interfacing the microcontroller to the detector is relatively simple. The output of the detector front-end is connected to pin 4 on port 1 (P1.4), which is configured to generate an interrupt for every input pulse. The interrupt service routine simply increments a variable representing the number of pulses counted in the past minute, exits, and lets the microcontroller go back to sleep. (See Listing 1 (available on our website at **www.nutsvolts.com**) and Figure 2.)

One of the unique architectural features of the MSP430 series of microcontrollers is the ability to use multiple clock sources of different frequencies for the many peripherals. In low-power microcontroller design, it is often desirable to use a low clock speed to save power. However, use of a slow clock would result in slow response times to interrupts. With the MSP430, it is possible to have a clock for program execution and a different clock for Timer_A for measuring time intervals. While the controller is in sleep mode awaiting interrupts, a low-power 32kHz watch crystal is used to keep track of time. When an interrupt does occur, the controller awakens from sleep and uses the faster built-in RC clock for quick service. This enables a fast response without compromising on power use.

In order to make the user interface responsive, the display is updated every second with a running average of the counts detected per minute. In software, this is implemented using a circular array of 60 elements each containing the number of counts detected in one second. The numbers are updated once a second such that the newest count overwrites the oldest count. This running average method allows you to see the levels change without waiting long periods of time for display updates. For even quicker results, an instantaneous CPM is provided so that

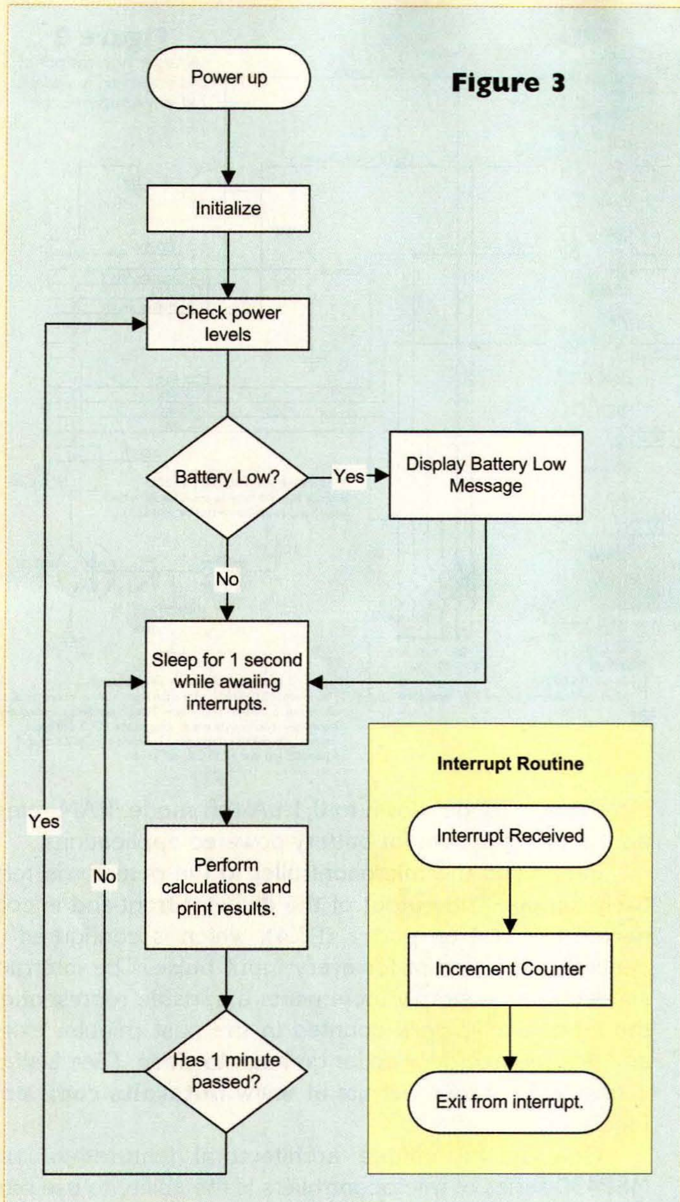


Figure 3

the user can see the level change within a second without waiting for the running average to settle. (See Listing 2 on our website and Figure 3.) If an alarm feature is desired, a buzzer could be connected to the microcontroller which would be activated whenever the counts per minute rose above a certain level.

LCD Interface

I used a 16-character by two-row display module with a built-in Hitachi 44780 LCD controller, available from electronics surplus suppliers. However, these require five volts to operate, and the digital interface won't be happy with the 3.3-volt logic levels from the MSP430. I attempted to find some low-power voltage-level translation chips that consume very small amounts of power, but it was difficult to find something that drew less quiescent current than the microcontroller itself in sleep mode. So I came up with another idea — why not use the CD4066 quad-bilateral analog switch? It has a quiescent current drain of 0.01 uA (that's right, 10 nanoamps) and can easily operate in the MHz range. That way, the microcontroller can "toggle" five volts into the input of the five-volt logic device, at extremely low-power consumption and cost (35 cents per chip). See Figure 4.

The LCD provides either an eight- or four-bit parallel interface. There are preprogrammed chips available that can be used to interface the LCD to the microcontroller in serial mode. However, to reduce cost, the LCD is directly interfaced in four-bit parallel mode to the MSP430F1121.

Analog-to-Digital Converter

Since the microcontroller is operated from batteries, it should be aware of the condition of its power source. However, the MSP430F1121 does not have a flash ADC, so analog-to-digital conversion has to be done in software. With the help of an internal comparator, a sigma-delta-type ADC (as described in the TI application note SLAA104: "An MSP430F11x1 Sigma-Delta type Millivolt Meter") is implemented to read analog voltages.

The output of a one-bit DAC (the R/C combination) is seen at the inverting input of the comparator. The other input is connected to the voltage in question. The ADC assembly routine operates by increasing the pulse width of the output, thus raising the average voltage across the capacitor. When the capacitor voltage is higher than the input voltage, the comparator switches, thus signifying to the routine that the DAC voltage matches the input voltage. The final value of the pulse width is proportional to the input voltage measured, allowing the actual voltage to the calculated. Use of this ADC can theoretically yield arbitrarily high precision since the resolution is determined by the number of steps divided into the full pulse width. The drawback to higher precision is a longer time required for sampling, making the method more suitable for slowly changing signals. See Figure 5.

Normally, the voltage output from the port pin would be VCC, or 3.3 volts in this case. However, the voltage that powers the microcontroller may vary due to the condition of the batteries if a regulator is not used. This fluctuation causes the use of VCC as a reference to be unreliable. A cheap and effective solution is to use a 1.8-volt zener diode across the capacitor. As long as the breakdown voltage of the zener is less than the minimum voltage that VCC will reach, the output of the charge voltage across

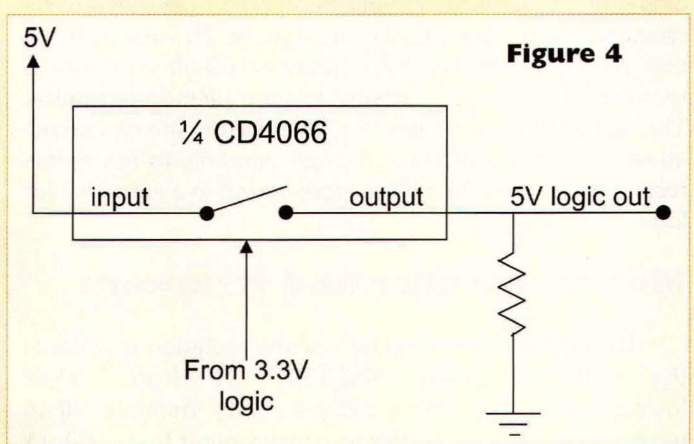


Figure 4

the capacitor will be constant.

In the more complex prototype, voltage sampling is necessary to get a good idea of how much power is being used by the device. In the event that the power source is running low, the microcontroller can shut off peripherals to save power. You could imagine how that could be implemented using say, a MOSFET to control the power to the inverter for the detector. Or the microcontroller could raise a "battery low" signal. You could easily connect other sensors to the input, such as a temperature sensor or a light sensor. What you can do with the measurement information is entirely up to your imagination.

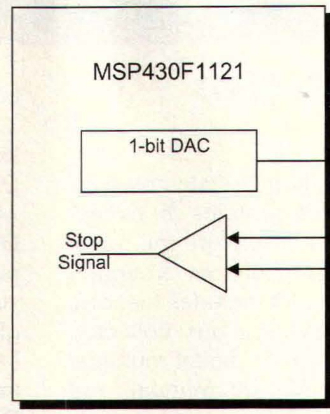


Figure 5

Implementation Notes

The inverter/detector front-end was built on a separate circuit board to physically separate the high voltages (90-150 volts) from the low voltages used in the logic circuitry. The neon bulb is attached to wires so that it can easily be located anywhere in a project case for maximum exposure to the radiation source. Please note that the detector's resistor settings need to be determined experimentally before making a permanent version. Not all neon bulbs are built alike — I've encountered bulbs with 75, 99, or even higher ionization voltages. Depending on what you find in your junk box, the zener diode's breakdown voltage should be above that of your neon. Potentiometer R6 is set such that the voltage across the neon is just below the ionization voltage. See Figure 6 for a picture of the radiation monitor in its more complex form.

The microcontroller can be used as part of the evaluation board from TI, connected through a header, or as a stand-alone integrated circuit, with a watch crystal attached. I used the evaluation board for ease of programming and chip replacement. The evaluation board is connected through a 26-pin ribbon cable to a header on the radiation monitor. Ensure that the pin translations are done properly when using the chip directly. The C compiler and binary file downloader can be obtained from TI's website (**www.ti.com/msp430**) along with the datasheets and application notes. Note that the neon bulb can actually be triggered by ambient light if not shielded properly. You can use a layer of electrical tape or some other opaque material to block the light while still allowing beta and gamma radiation to pass through.

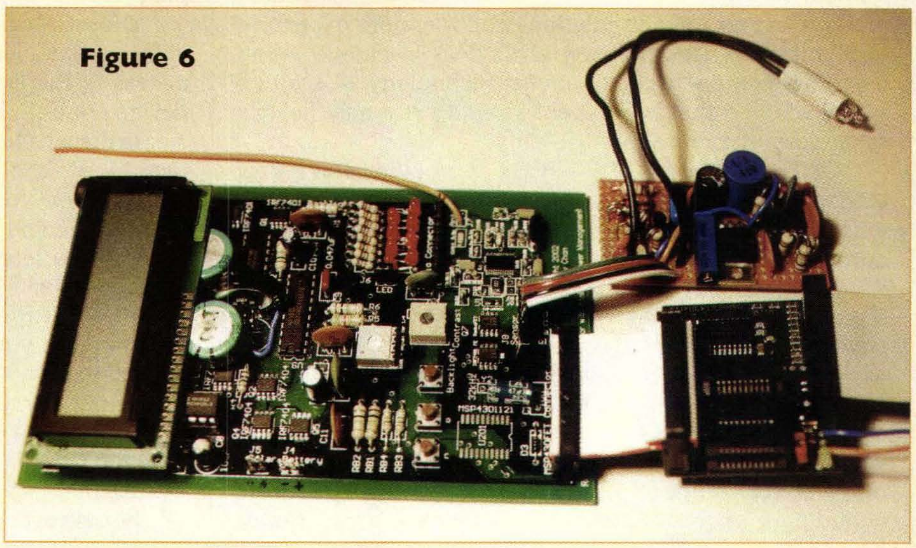
You can use three fresh 1.5-volt batteries in series to get about five volts for the LCD module, and use the suggested ultra-low quiescent current linear regulator for the microcontroller. Or you could use a single cell DC-DC converter to obtain five volts from a single 1.5-volt battery to save space. (The DC-DC converter is not used in this article to keep things simple and costs low.) Or simply use a "wall-wart" and an LM7805 regulator to get a cheap and clean five volts.

Conclusion

It is easy to add more features to the existing radiation monitor such as an external relay triggered by the alarm signal. The modularity of the design allows other detectors to be used — like an actual Geiger tube and its associated 600-volt power supply. You could also just use pieces of this project for other purposes, such as building an electronic light meter. Or you could use the inverter alone as a small DC-DC converter for another project. There are numerous sources from journals and on the Internet on radiation detectors and experiments. Firing up your browser and aiming it at **www.google.com** would be a great way to start.

As with any project involving high voltages, care must be taken to insulate the wires well, preventing low-voltage wires from touching the high-voltage ones. Though the inverter's current output is small, you could still get a nasty shock if you accidentally touch the high-voltage wires while it is in operation! In addition, care must be taken when using any radioactive sources. Though alpha sources are relatively harmless in terms of penetrating ability — if ingested — the radioactivity may cause serious damage to the internal organs. A good understanding of the possible effects of radiation exposure is imperative before experimenting with radiation. With these precautions in mind, happy experimenting! **NV**

Figure 6



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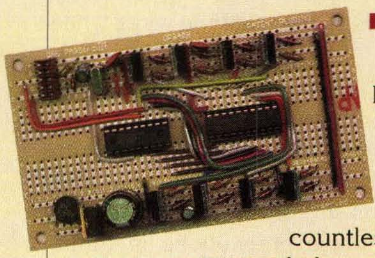


The patent(s) pending ONE PASSystem™ is a "complete circuit" approach to small circuit design. While breadboards offer an area to experiment with ICs, they lack any efficient way to support countless other active and passive components needed to complete a working circuit. A number of products such as carrier/development boards are application specific solutions and therefore expensive and limited in use. The new ONE PASStructure™ — an asymmetrical open circuit socket technology — is a universal solution that is inexpensive and extremely flexible regardless of application.

ONE PASSircuit™ PCBs combine this new technology with a standard breadboard pattern to create a user-friendly environment where ICs, active and passive components of all types can coexist in a very small space. Landing pads for passive devices are organized in a patent pending array, resulting in various sizes of both powered and isolated two, three, and four-pin sockets, allowing the user to quickly and easily build power supplies, voltage dividers, feedback loops, RC, LC, crystal and transistor circuits, even use pots and IF transformers without loss of IC space! These amazing new boards cover a wide range of complex analog and digital uses including microprocessors, robotics, and motor controllers.

The OP840B, only $6.95 with 840 tie points can hold six 14-pin or five 18-pin ICs and up to 14 transistors. The OP1170B, only $8.95 with 1170 tie points can hold nine 14-pin or seven 18-pin ICs and up to 20 transistors. The OP1210B, only $8.95 with 1210 tie points can hold six 14-pin or five 18-pin ICs and up to 28 transistors. To support your circuit's connectors, controls, and displays, while giving your project that finished look and feel, all ONE PASSircuit PCBs fit directly into ABS plastic cases that include both plastic and aluminum covers from RadioShack®.

For more information, contact:

ONE PAS, INC.
P.O. Box 108, Dept. NV
Woodstock, IL 60098-0108
815-337-3754
Email: **sales@onepasinc.com**
Web: **www.onepasinc.com**

CONTROL ANY SERIAL DEVICE VIA THE INTERNET

SerialHost will let you customize any serial string and send it remotely to a device connected to the server. Send commands directly out the RS232 port on your computer from any web browser.

SerialHost includes source code for a sample plug-in, and documentation on how to compile and load your custom device plug-in. Remote control your server by hosting interactive "web pages" or simply by accepting an URL request or Java applet command from a remote page on the Net. Essentially, publish any device connected to your computer's RS232 port to the Internet.

SerialHost offers two modes of communication between your browser or applet and a specific device plug-in.

Direct Mode: A user's I/O is passed on to the plug-in for communication. At this point, the user has no direct access to the DAP server and is 'logged in" to a specific device control plug-in.

Indirect Mode: A user will be able to map I/O to the plug-in of choice. This allows more complex client applications to communicate with multiple plug-ins without needing multiple connections.

Another feature lets you create serial commands and list them as an (<a href=) link, making it possible to create a simple "URL hot-link" on a graphic and send a command to your plug-in device. Example: A room on a floor plan image for instance, selected as a link can send a command to your serial device. Have a serial-controlled video switching device switch to the camera in that room. Use one video card and have a 16-channel input device or control pan and tilt servos.

SerialHost Server Software, Plug-in Manager, and web control components will sell as a package for $75.00.

For more information, contact:

SERIALHOST
Jon Farhat, President: **jon@serialhost.net**
Steve McFarlin, Head of Development:
steve@serialhost.net
Email sales: **info@serialhost.net**
Email tech support: **support@serialhost.net**
818-567-0373

TINY LOW-POWER COMPUTER OFFERS COMPACTFLASH OS

Persistor Instruments announces the Persistor® CF2 — a 2.5" x 2.0" x 0.7" single-board computer offering features desirable to developers of remote or portable equipment for data logging or control applications. Both OEM designers and researchers will find the CF2's small size, low power, removable memory, and comprehensive programming libraries ideal for rapid and reliable product or project development.

The CF2 combines a 3.3V 16MHz Motorola 68332 with a Texas Instruments MSP430 to offer several ways to achieve very low-power consumption. Its programmable clock speed allows operation down to 5mA, stop modes at 250uA, and a suspend mode below 10uA. Sleeping systems can wake from external interrupts, RS-232 activity, or timers maintained by the MSP430 functioning as the real-time clock and power manager.

The CF2's PicoDOS® operating system and configurable command shell lets users manage files and directories on removable CompactFlash (CF) cards using familiar DOS-like commands. Additional commands permit access to CF2 hardware parameters such as the real-time clock, RS-232 settings, virtual EEPROM variables, and optional hard drives.

The tiny CF2 is packed with 1MB of onboard flash, 512KB of RAM, a 3.3-volt linear regulator, a dual RS-232 driver, and battery backing circuitry.

The Persistor CF2 is available now, priced from $395.00 for one to $295.00 in large OEM quantities. Developer's kits are available starting at $495.00.

For more information, contact:

PERSISTOR INSTRUMENTS
254-J Shore Rd., Dept. NV
Bourne, MA 02532-4104
508-759-6434
Email: **atinfo@persistor.com**
Web: **www.persistor.com**

Build the CF-MOSFET Audio Power Amplifier PART 2

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

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!

Last month, we examined a detailed description of the theory and operation of the CF-MOSFET audio power amplifiers. In this final article, the construction and implementation of the CF-MOSFET design will be detailed, along with application information, and a variety of options.

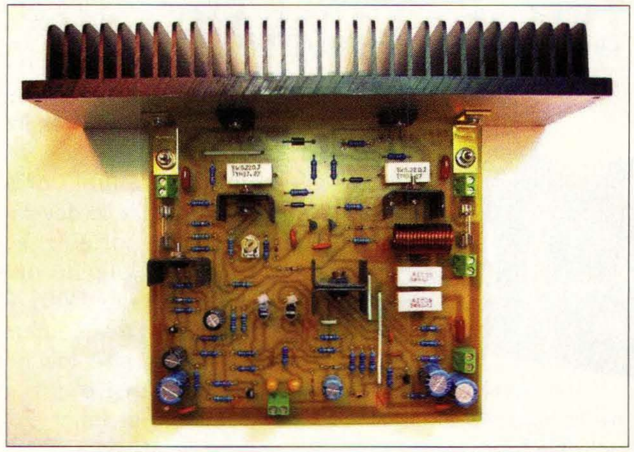


PHOTO 1: Top view of completed CF-MOSFET amplifier module. Note this unit utilizes the "professional" type main heatsink.

Amplifier Construction

As with most audio power amplifiers, the actual construction of the CF-MOSFET amplifier is relatively easy (much easier than the physics and theory involving its operation!). A double-sided PC board is not required, the printed circuit artwork is larger and easier to reproduce, the components are larger, and component spacing is not overly-critical. A "reflected" illustration of the artwork is provided in Figure 1, which can be lifted and used to etch your own PC board, or a pre-etched/pre-drilled PC board can be purchased from the supplier referenced in the parts list.

The "top-view" component layout is illustrated in Figure 2, and the "top-view" component layout showing the PC board artwork is illustrated in Figure 3. By examining the parts list together with the top-view layout illustrations, I believe the construction is somewhat self-explanatory, but there are a few details that need to be touched on.

Figure 2 illustrates the four component-side jumpers that must be installed. These should be fabricated from solid-conductor 20-AWG insulated wire. I used commonly-available "sil-pad" insulators in mounting the medium-power transistors to the smaller heatsinks, and also in mounting the L-MOSFETs to the large heatsink. Mica insulators coated with heatsink compound can be substituted, but they are more "messy." Note that an insulator is not required between the mounting face of Q11 and the front face of Q14. The output inductor, L1, is fabricated by winding 18 turns of #14-AWG magnet wire around a 1/2" diameter form (such as a piece of scrap wooden dowel). TB1 through TB5 are two-position terminal blocks, even though only one connection is needed for TB1, TB3, TB4, and TB5 (TB2 utilizes both terminals – one for the line-level input signal and the other for the shield ground). I chose this technique primarily because single-position terminal blocks are difficult to find. However, the two-positions can come in handy in some installation situations.

Before installing Q1 and Q2 into the PC board, physically tie them together with a small tie wrap, and then bend the leads out to fit into the PC board. This provides a greater degree of temperature tracking between the two devices. Follow the same procedure when installing Q3 and Q4. Q3 and Q4 must be beta matched to within 10% of each other. If you don't have a meter or transistor tester than can measure beta for matching purposes, you should purchase Q3 and Q4 as a "matched pair" from an electronics dealership.

Photo 1 illustrates a top-view of a finished CF-MOSFET amplifier, showing most of the construction details discussed in this section.

Power Output Options

The overall component specifications and

Tools that will be helpful, but not absolutely necessary:

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

design of the CF-MOSFET amplifier topology is capable of accommodating dual-polarity power supply voltages up to 60 volts DC. This equates to a maximum output power capability of about 160-watts RMS into typical eight-ohm speaker loads (assuming normal power supply droop under heavy loading). I designed the CF-MOSFET amplifiers to utilize two separate types of L-MOSFET output devices, depending upon the power requirements. For a maximum output power capability of up to 100-watts RMS, the Hitachi 2SK1058/2SJ162 complementary pairs, or the SemeLab BUZ900P/BUZ905P complementary pairs, should be installed. For higher output power capabilities, up to about 160-watts RMS, the SemeLab BUZ900DP/BUZ905DP "double-die" L-MOSFETs should be installed.

The standard 100-watt version of the CF-MOSFET amp will require a main heatsink with a thermal resistance rating of approximately 0.5 degrees C/watt. Note that the PC board assembly mounts to the heatsink with two common 1" L-brackets, as illustrated in Photo 1. If you want to save some money and use up some old heatsinks that are probably collecting dust in your junk box, you can construct your own custom heatsink. Photo 2 illustrates how this can be accomplished. For my heatsink, I utilized 10 common-style TO-3 type heatsinks mounted to an aluminum plate, measuring approximately 11" wide by 4" high by 1/8" thick. Note that the TO-3 heatsinks are simply mounted back-to-back, with the aluminum plate sandwiched between them.

I discovered this home-built heatsink design to be adequate for continuous power output levels of 70-watts RMS but, as you can see from the photo, I could have made more efficient use of the available space on the aluminum plate and mounted more smaller heatsinks for improved dissipation capabilities. Nevertheless, my design should provide you with a basic "feel" for the heatsink you might like to construct, depending on your needs and junk box materials. Also, keep in mind that the enclosure you decide to mount the finished amplifier(s) into could take the place of the aluminum plate. For example, the output devices could be mounted to the rear panel of an appropriate enclosure, with the smaller TO-3 heatsinks mounted to the inside and outside surfaces of the rear panel (in fact, this is very similar to the method used in the classic "Tigersaurus" power amplifiers of the 70s).

If you decide to construct the "high-power" version of the CF-MOSFET amplifier, besides installing the double-die L-MOSFETs, you will need to increase the current rating of F1 and F2 to five amps, and increase the size of the main heatsink to a unit providing a thermal resistance of approximately 0.35-degrees C/watt. Commercial heatsinks of appropriate ratings are available from SEAL Electronics (contact information is provided in the parts list), and they are often available from surplus electronic dealerships.

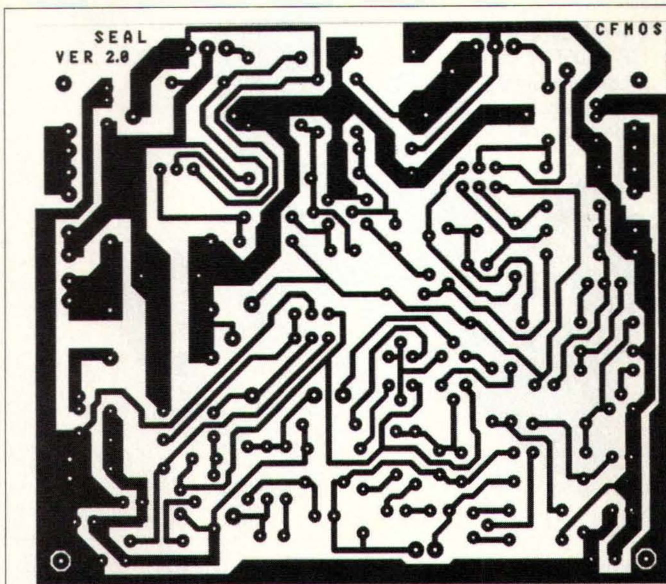


FIGURE 1. Bottom view (reflected) copper artwork illustration (shown at 50%).

Amplifier Connections

Figure 4 illustrates the correct method of wiring one CF-MOSFET amplifier module to an appropriate power supply. Power transformer T1 should have a 70-volt center-tapped secondary rated at three amps (i.e., 210 VA). This will provide approximately 105-watts RMS of output power into an eight-ohm speaker load. The line fuse (F1) should

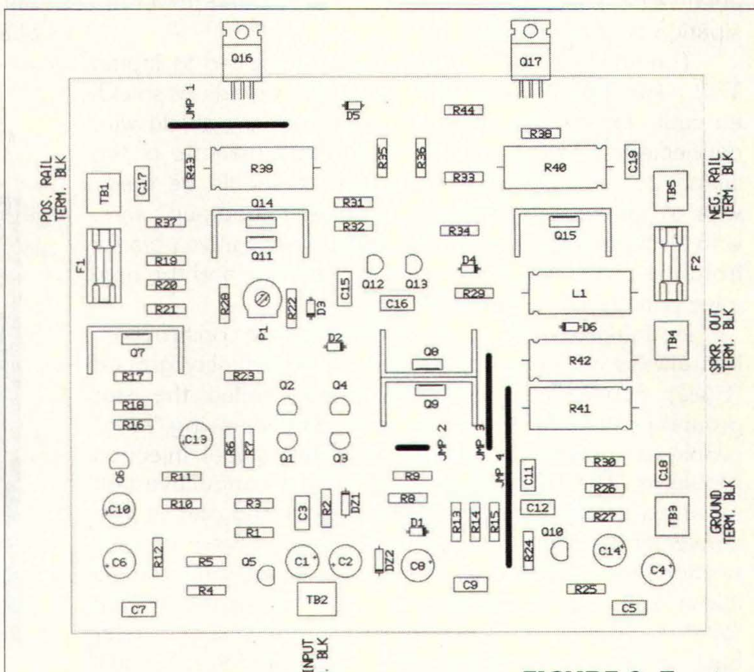


FIGURE 2. Top view component layout.

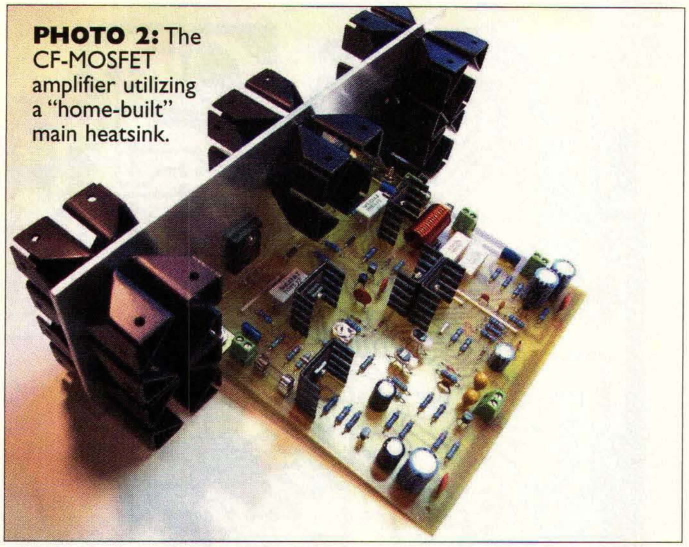


PHOTO 2: The CF-MOSFET amplifier utilizing a "home-built" main heatsink.

be a two-amp "slow-blow" unit. The illustrated "X capacitor" is incorporated to reduce high-frequency rectification noise that could be fed back into the AC power line, and it also serves to filter out many types of RF noise that could be introduced into the amplifier from the AC line. The X capacitor should have an AC voltage rating of at least 250 volts for domestic 120 VAC residential power. BR1 is any common type 25-amp, 200-volt bridge rectifier. C1 and C2 are the power supply's reservoir capacitors; these are both 10,000 uF units rated for 63 VDC. C3 and C4 help to remove RF rectification noise. They should be ceramic types and rated for at least 100 volts. R1 and R2 are "bleeder" resistors, incorporated to bleed off any dangerous charges on the reservoir capacitors in the event that one (or both) of the amplifier's rail fuses blow. R1 and R2 can be 10 Kohm, half-watt devices, but the actual resistance value is not critical, as long as their rated power dissipation is not exceeded.

The line-level audio input signal is applied to inputs TB2-1 and TB2-2. It is best to use a good grade of shielded cable for the input signal wiring, with the shield wire connected to TB2-2 as illustrated. The remainder of the wiring connections shown in Figure 4 should be made with a good-quality stranded, insulated "hook-up" wire, with a minimum gauge of #20 AWG. The positive polarity from the power supply is connected to TB1 and the negative polarity is connected to TB5.

In high-gain, high-power audio amplifier construction, it is always necessary to establish a high-quality ground (HQG) connection point (sometimes called the star ground point). This technique eliminates annoying "hum" problems created by ground loop and signal injection problems. The HQG point is typically a conductive bolt mounted through the enclosure chassis and placed in a convenient location. All ground (or circuit common) connections are made to this central HQG point, thus making it impossible for AC interference signals superimposed on "one" ground line to be mixed with others. If you refer back to the schematic diagram in Figure 4 of Part 1, you'll note that the input signal and negative feedback circuits have their own independent ground line, which is the input signal "shield" connection point (TB2-2). As Figure 4 illustrates, a dedicated ground wire must be connected from TB2-2 to the HQG point, and this keeps the high-gain signal and feedback grounds from being contaminated by AC components from the amplifier's decoupling circuits or any other source of signal injection.

The output to the speaker system is taken from TB4 and the circuit ground. Normally, the TB4 output is labeled "+" (although there isn't any real polarity associated with it), and it is typically connected to the "red" speaker connection at the rear of the amplifier enclosure. The negative (-) side of the speaker output is connected to the HQG point, and typically connected to the "black" speaker connection at the rear of the amplifier enclosure.

Since the 120 VAC mains power is isolated through the action of T1, it is not mandatory to provide for an earth ground connection, but it is certainly a good idea. The earth ground wire from the AC power cord can be connected to any location on the chassis that provides continuity to the HQG point.

Power Supply Tips and Options

The design of the CF-MOSFET amplifiers is such that they will stabilize and operate properly with power supply rail voltages as low as 24 VDC, which equates to an output power level of approximately 25-watts RMS into eight-ohm speaker loads. Obviously, this means that a very wide range of dual-polarity unregulated DC power supplies can be incorporated for operational power, depending on the application needs.

If you desire to construct the high-powered version of the CF-MOSFET amplifier, T1 of Figure 4 will need to have a center-tapped secondary rating of 84 volts at five amps. Such a transformer will provide dual-polarity voltage rails of approximately 60 volts DC. In addition, reservoir capac-

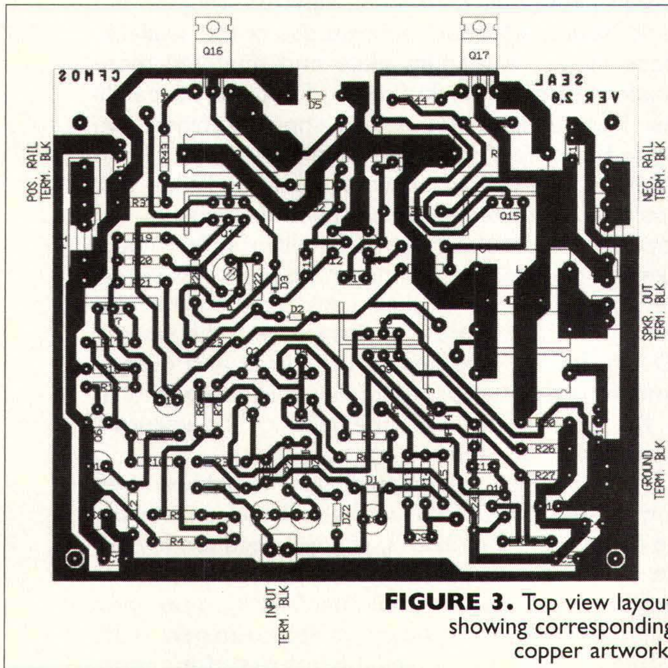


FIGURE 3. Top view layout showing corresponding copper artwork.

itors C1 and C2 will need to be rated for at least 75 WVDC, and F1 should be a three-amp, slow-blow type.

Dual-polarity "raw" DC power supplies, as the type illustrated in Figure 4, will draw a significantly large surge current to charge the reservoir capacitors when the AC mains power is first applied. Therefore, for maximum reliability, it is desirable for the power switch (S1) to have a fairly high current rating — a 15 amp to 25 amp rating would be a good choice. When installing the power supply components and amplifier module into an appropriate enclosure, it is best to keep the physical location of the power transformer as far away as possible from the sensitive, high-gain areas of the amplifier circuitry (i.e., the input stage area of the PC board).

Such a technique will minimize undesirable hum pick-up from the radiated EMI field of the power transformer. Toroidal and shielded transformers are preferred for the minimum EMI radiation, but even these transformer types can induce some hum if placed too close to sensitive circuitry. If it is impossible to achieve reasonable spacing of such components (due to inadequate enclosure size), the power transformer can be placed in a small ferrous cage (such as used in computer switch-mode power supplies) to minimize EMI leakage.

Figure 5 illustrates a method of constructing an appropriate "low-cost" power supply for the CF-MOSFET series amplifiers that will not compromise performance, albeit the maximum output power of the amplifier will be reduced to approximately 60-watts RMS into eight-ohm loads (approximately 90-watts RMS into four-ohm loads). The power transformer can be fabricated from two commonly-available (and inexpensive) power transformers with secondary ratings of 25.2 volts at three amps. The transformer secondaries are placed in series (as illustrated), with the common connection point becoming the "center-tap" for the fabricated transformer. Such a configuration will provide approximately 40-volt dual-polarity rails. Also, if this power supply design is chosen, the voltage ratings of C1 and C2 can be safely reduced to 50 VDC. Such capacitors are less expensive and commonly available through Jameco. The Figure 5 power supply design will match very well with the previously discussed "home-built" main heatsink design. Therefore, if you would like to construct a true "audiophile-quality" power amplifier at minimum expense, you could choose to build your own main heatsink and utilize the "fabricated transformer" design in Figure 5.

Some audiophiles prefer to construct audio power amplifiers in monoblock (or monaural) configurations, with each amplifier channel operating from its own dedicated power supply. Other audiophiles prefer to construct amplifiers with multiple channels operating from a common power supply. With either option, the performance of the CF-MOSFET amplifiers will not be significantly affected, due to the high PSRR characteristic of the design. However, if you desire to operate multiple amplifier channels from a single power supply, the power transformer current ratings and the total reservoir capacitance will have to be increased accordingly.

Final Testing and Adjustment

After the CF-MOSFET amplifier(s) are installed in an enclosure and connected to an appropriate power supply, the proper operation can be tested in several ways, depending on the available test equipment. Begin by adjusting the Vbias potentiometer (P1) to its "center" position. Using a few clip leads, temporarily connect a voltmeter from the drain of Q16 to the drain of Q17. If the voltmeter is not an autoranging type, set it to the 20-volt range. Do not connect a speaker load or input signal at this time. Set the power switch (S1) to the "ON" position.

If you have a "Variac" (i.e., a variable AC power source), plug the line cord of the amplifier into the Variac and slowly adjust the Variac up to about 60 volts AC, while monitoring the voltmeter. If the voltmeter reading

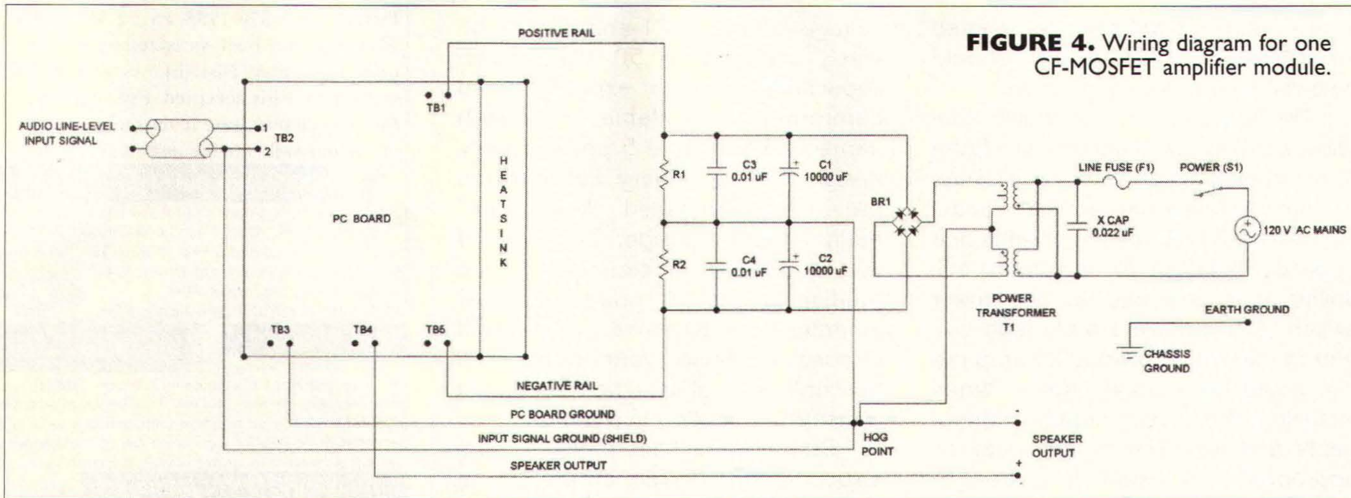


FIGURE 4. Wiring diagram for one CF-MOSFET amplifier module.

begins to approach a one-volt level, you have a fault that needs to be corrected before proceeding. Typically, this voltage should be a few hundred millivolts, or less. While leaving the Variac set to a 60-volt level, adjust P1 for a voltage reading of 20 millivolts. Turn off the Variac and disconnect the voltmeter. Connect the voltmeter from the speaker output terminal (TB4) to the HQG point and re-apply power to the Variac (still leaving it set at about 60 volts AC). This DC offset voltage should be about 10 millivolts, or less.

Adjust the Variac up to the nominal 120 VAC line voltage while monitoring the voltmeter. The DC offset voltage may increase up to about 20 millivolts to 30 millivolts, depending on how well matched the differential input transistors (Q1 and Q2) happen to be. The actual value of this offset voltage is unimportant, as long as it is not in excess of 50 millivolts (the polarity may be in either direction). Turn off the Variac and re-connect the voltmeter between the Q16 and Q17 drains once again. Re-apply power to the Variac, leaving it set to the nominal 120 VAC line voltage. Adjust P1 for a drain-to-drain bias voltage of 20 millivolts. Turn off all operational power to the amplifier and Variac. With the aforementioned procedures completed, the CF-MOSFET amplifier is properly tested, adjusted, and ready for use.

If you do not have a Variac, the following alternate procedure can be followed. Temporarily wire a standard 100-watt incandescent light bulb in parallel with the power switch (S1), and set S1 to its "OFF" position. Connect a voltmeter between the Q16 and Q17 drains as described in the previous discussion. Plug the amplifier line cord into a 120 VAC outlet, and carefully observe the action of the light bulb and the reading of the voltmeter. The light bulb should illuminate briefly, and then go dim as the initial surge current diminishes. If the light bulb stays brightly illuminated, there is a problem in the amplifier that needs to be corrected before proceeding.

If the light bulb dims properly, check the voltmeter reading to insure that it is not in excess of a few hundred millivolts. Adjust P1 for a voltmeter reading of approximately 20 millivolts. Unplug the amplifier line cord and disconnect the voltmeter. Connect the voltmeter from the speaker output terminal (TB4) to the HQG point and plug the line cord back into the AC outlet. The DC output offset should be in the 20 millivolt to 30 millivolt range. Unplug the line cord and disconnect the light bulb. Reconnect the voltmeter between the Q16 and Q17 drains, as before, and plug the line cord back into the AC outlet. Set the power switch (S1) to the "ON" position, and adjust P1 for a voltmeter reading of 20 millivolts (it will probably still read 20 millivolts from the previous setting). Disconnect all operational power. The CF-MOSFET

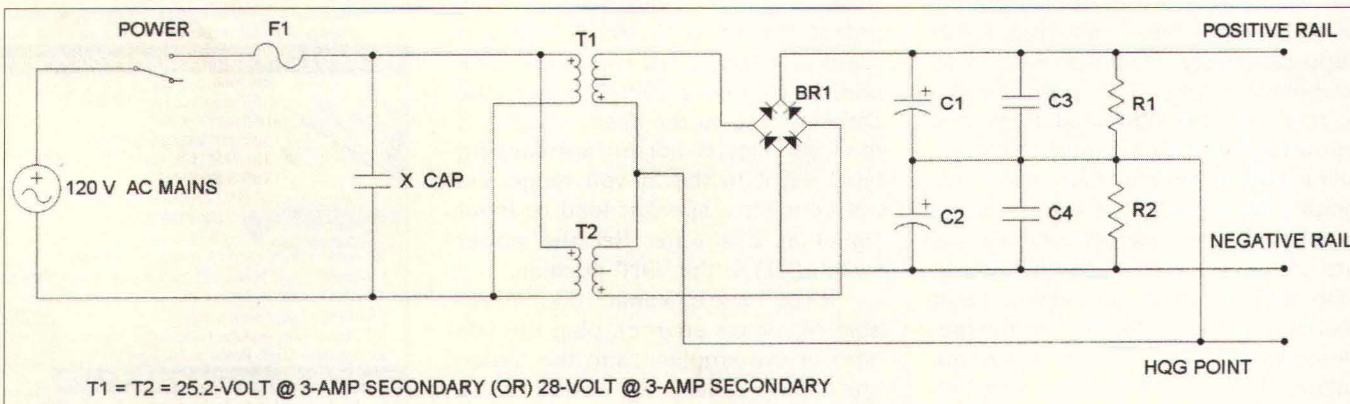


FIGURE 5. Alternate method of constructing the amplifier's power supply utilizing two inexpensive power transformers.

amplifier is now tested, adjusted, and ready for use.

Final Comments

The CF-MOSFET series audio power amplifiers are intended for the serious hobbyist or professional desiring a no-compromise design for a wide variety of audio applications. The incorporation of L-MOSFETs and the increased circuit complexity force the construction cost to be a little higher than many generic designs, but the sonic purity and long-term reliability will be well-worth the cost difference to most audiophiles. **NV**

PARTS LIST FOR THE CF-MOSFET AUDIO POWER AMPLIFIER MODULES

RESISTORS (All fixed resistors are 1/2-watt, 1% metal film units, unless otherwise noted.)

R1 — 100 Kohm
R2 — 220 ohm
R3, R11, R12, R14 — 10 Kohm
R4, R6, R7, R28, R29, R37, R38 — 100 ohm
R5 — 3.3 Kohm
R8, R9, R18 — 68 ohm
R10, R16, R17, R25, R26 — 1 Kohm
R13, R15 — 330 ohm
R19 — 15 ohm
R20 — 680 ohm
R21, R22, R35, R36 — 270 ohm
R23 — 150 ohm
R24 — 6.8 Kohm
R27 — 22 ohm
R30 — 10 ohm
R31, R34 — 15 Kohm
R32, R33 — 120 ohm
R43 — 1.2 Kohm
R44 — 820 ohm
R39, R40 — 0.22 ohm, 5 watt
R41, R42 — 8.2 ohm, 5 watt

CAPACITORS

C1, C2 — 47 uF, 25 volt, tantalum
C3 — 68 pF, 100 volt, ceramic
C4, C6, C8, C14 — 220 uF, 100 volt, aluminum electrolytic
C5, C7, C15, C16 — 0.01 uF, 100 volt, ceramic
C9 — 5 pF, 100 volt, ceramic
C10, C13 — 47 uF, 100 volt, aluminum electrolytic
C11 — 1000 pF, 100 volt, ceramic
C12 — 100 pF, 100 volt, ceramic
C17, C18, C19 — 0.1 uF, 100 volt, mylar

SEMICONDUCTORS

Q1, Q2, Q5, Q6, Q13 — 2N5401 PNP transistor
Q3, Q4, Q10, Q12 — 2N5551 NPN transistor
Q7, Q15 — 2SB649 PNP transistor
Q8, Q9, Q11, Q14 — 2SD669 NPN transistor
Q16 — 2SJ162 (or) BUZ905P P-channel lateral MOSFET
Q17 — 2SK1058 (or) BUZ900P N-channel lateral MOSFET
Q16 (high-power version) — BUZ905DP "double-die" P-channel L-MOSFET
Q17 (high-power version) — BUZ900DP "double-die" N-channel L-MOSFET
D1, D2, D3, D4 — 1N4148 silicon diode
D5, D6 — 1N5060 silicon diode
DZ1, DZ2 — 3.9 volt, 1/2 watt zener diode

MISCELLANEOUS

F1, F2 — Three-amp GMA fast-blow fuses
GMA fuse clips (four needed) — Jameco #102859
L1 — 2 uH air core inductor (see text)
P1 — 1 Kohm, 8 mm "horizontal mount" trim pot. RadioShack #900-7442
TB1, TB2, TB3, TB4, TB5 — Two-position terminal blocks. Jameco #160784
TO-220 heatsinks (five needed) — Jameco #129242 or equivalent
1" L-brackets (two needed) — Most hardware stores
PC board — See text and illustrations
Main heatsink — See text and illustrations
Misc. — Semiconductor insulators, mounting hardware, hook-up wire, solder, etc.

NOTE: The following items are available from **SEAL Electronics,** P.O. Box 268, Weeksbury, KY 41667; Tel. 606-452-4135; email **<sealelec@eastky.net>** URL **www.sealelectronics.com.**

Complete kit of all parts, including drilled and etched PC board, and "professional-style" main heatsink:
(100-watt version) — $140.00, plus $10.00 S&H (Canadian residents add $16.00 S&H)
(160-watt version) — $165.00, plus $10.00 S&H (Canadian residents add $16.00 S&H)
* Assembled and tested units of either version available for an additional $25.00 cost.

Drilled and etched PC board for one CF-MOSFET module — $32.00
Professional-style main heatsink (undrilled) — $35.00
Semiconductor devices, including L-MOSFETs, and a complete line of power supply components, are available by visiting our website. Mr. Slone welcomes questions or comments via the contact information provided.
* Kentucky residents please add 6% local sales tax on all purchases.

Additional sources: All of the semiconductor devices are available through **MCM Electronics** or **Parts Express** (MCM carries the Hitachi 2SK1058/2SJ162 L-MOSFET devices). The "BUZ" L-MOSFET devices are available from SemeLab through their "Magna-Tec" website. (SEAL Electronics carries all three L-MOSFET device types.)

by Colin Barnard

Water Flow Meter and Event Timer

Keep track of your water usage plus control your sprinklers with the same system.

With the current concerns about domestic water usage and conservation, I thought it would be worthwhile to design an electronic project that showed how much water I was using, and how much each quarter I owed the water authority. As a bonus, a seven-day, seven-event timer — primarily intended for sprinkler control — was added.

The Design

The brains behind this project is a PIC 16F873 microcontroller **[1]**, a 16 x 2 LCD display and a ready-made flow sensor **[2]** and solenoid **[2]**. The software was written in 'C' **[3]**.

The flow sensor is the most expensive part of this design, so this project can be built either as a combined unit or as a flow meter or event timer. The PCB has been designed so that all unused pins are available for future expansion or experimentation.

The maximum amount of water used is 999.999 in gallons or kiloliters, the maximum price per gallon or kiloliter is $(£)9.99, and the total price that can be shown is $(£)999.99. The onchip EEPROM is used to store the cost per unit and, after each sprinkling event, the water used and its cost is calculated and stored for future information.

The Circuit

As can be seen from Figure 1, the circuit consists of nothing more than the microcontroller, flow sensor, and solenoid (located off board), and a few ancillary components. The flow sensor's signal is connected to pin 5 of DIL connector JP3 and is read by the PIC's RC0 pin which counts the number of pulses from the sensor. The water solenoid (if used) is connected to pins 1 and 3 of JP3 and is switched via T1, a 2N2222A or equivalent. D2 is the flyback diode to prevent damage to the transistor and PIC when the solenoid switches off. Push buttons S2 and S3 are used for setting the day, current time, cost per gallon/Klt of water and,

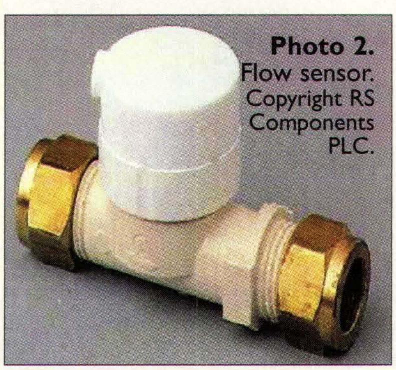


Photo 2. Flow sensor. Copyright RS Components PLC.

Photo 1. Solenoid.

of course, the timer on and duration times. S1 moves through the various menus (see Table 1).

Connector JP1 is for in-circuit programming and is laid out in the same order as the Microchip ICSP protocol. Diode D1 is to isolate the rest of the circuit from the high-level programming voltage required on the MCLR pin at programming time.

While not implemented here, if a reset button is required, then it should be hardwired between D1 anode and ground. The LED serves two purposes: an indication that the sprinkler is running (in timed or override mode), and to flash at approximately every half second to show a power failure has occurred. IC3 is not currently used, but see the software explanation for further details.

The power supply is standard; either a 9V AC or regulated 12V power pack at 600mA can be connected to the bridge rectifier. C3 is slightly larger than normal in value mainly to avoid any powerdips that may occur when switching the solenoid. It was found that the prototype circuit was sensitive to lights being switched on and off, and was causing the circuit to reset. This resolved itself with the higher-value capacitor. The regulator chip IC2 is a standard 78 series TO220 case. Port B is used for the LCD display which is used in standard four-bit mode. Connectors JP4 and JP5 bring the unused pins out for further expansion or experimentation. JP4 is connected to the RC6/7 pins of the PIC and these serve the dual purpose of connecting to the onchip UART, if required.

The Sensor and Solenoid

The solenoid (see Photo 1) used is specially designed for controlling water flow and is available in two models.

No special skills required.
For those who want to do their own programming ... a PIC programmer

The one selected here requires the water pressure to be a minimum of 0.2 bar with a flow rate of 1.32 US gallons (5lt)/minute when the fluid temperature is below 77° F and the ambient temperature is below 140° F. The solenoid is rated at 4W and can be driven by 12V DC (max 13.5V) or 24V AC.

It may be possible to use a standard 24V AC water solenoid from gardening centers, but this hasn't been tried. The coil resistance of the solenoid specified is a nominal 53 ohms and appropriate alterations to the circuit of T1 would need to be made if a relay or other solenoid was used. The inlet and outlet ports on the solenoid have 1/2" BSP threads.

The flow sensor in Figure 2 has an LED that emits light towards a detector diode; the force of water turns a wheel that interrupts the beam of light from the LED. Internally, the turbine is reminiscent of a miniature hamster wheel with electronics! The fluctuating LED light causes a change in output voltage from the detector diode. This voltage is amplified by the onboard amplifier, squared up by a Schmitt trigger, and arrives at the flow sensor's output transistor. The flow sensor has an onboard voltage regulator for the diodes and amplifier, and the output transistor is connected via an internal 10K ohm resistor to the supply voltage. The emitter diode requires an external resistor R8. Because the internal resistor connects to 5V, we get a squarewave with a maximum amplitude of 5V. Just perfect for a microcontroller's input pins.

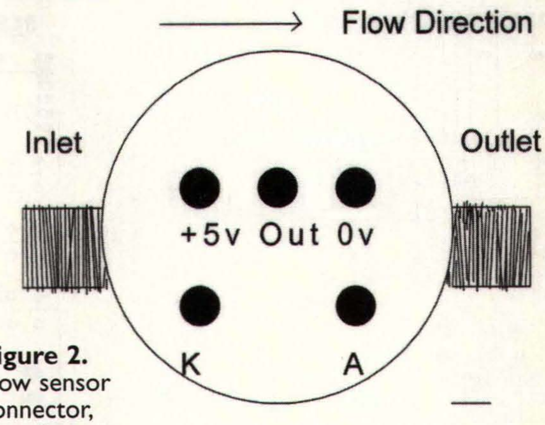


Figure 2. Flow sensor connector, view from top.

This particular sensor produces a nominal 1,200 pulses per one liter of water or 4542 pulse/1 US gallon. These are the pulses that are counted by the PIC's RC0 input in compare mode. When 1200 has passed, the counter is reset and the liters variable is incremented by one. This is the value which is marked in the software file that will need to be altered if a different sensor is used.

The sensor comes in two flavors and the one used

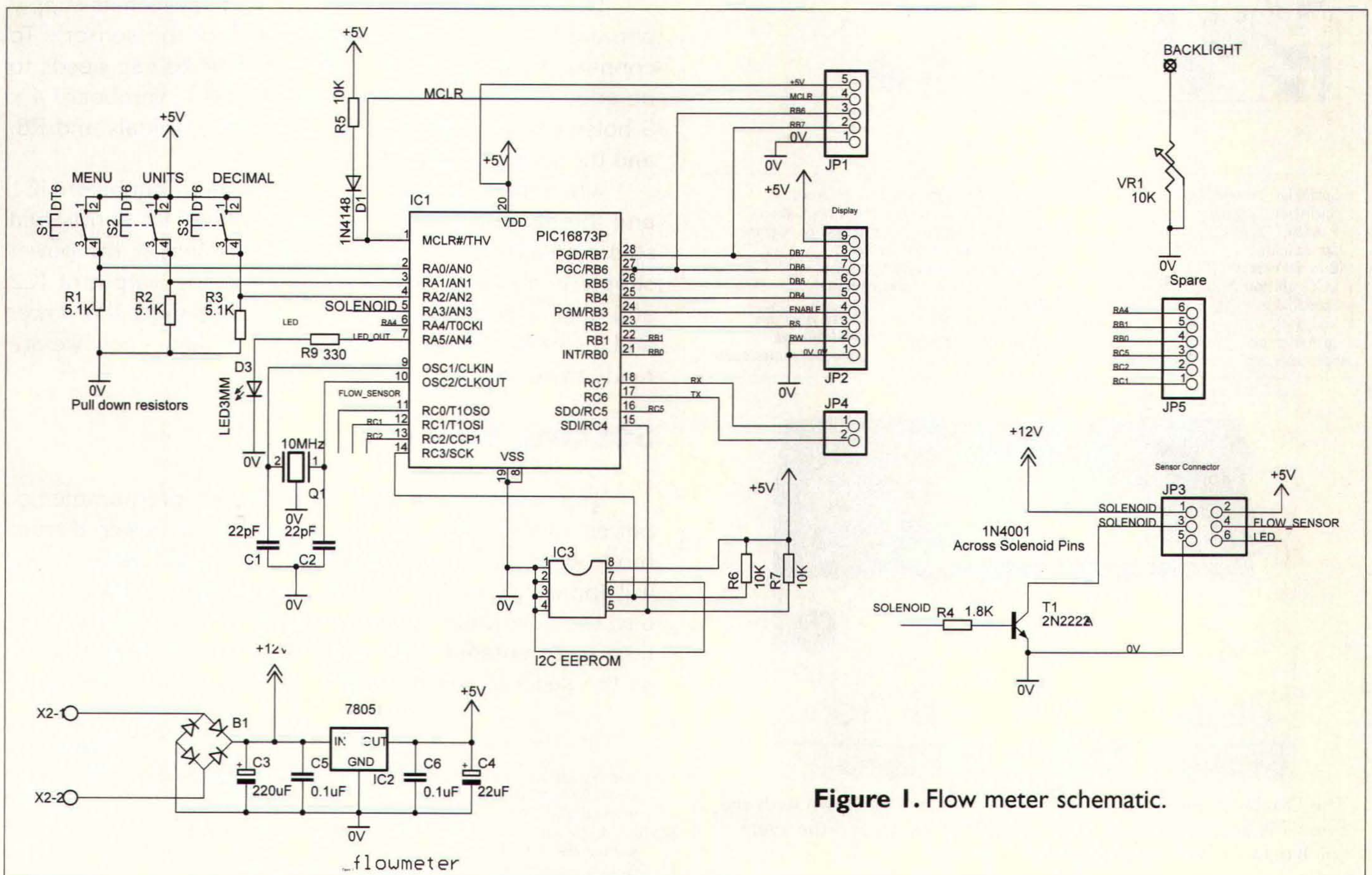


Figure 1. Flow meter schematic.

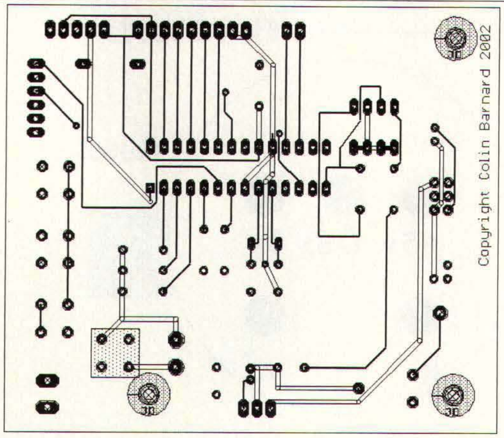


Figure 3a. PCB tracks upper side. **3.68" x 3.2"**

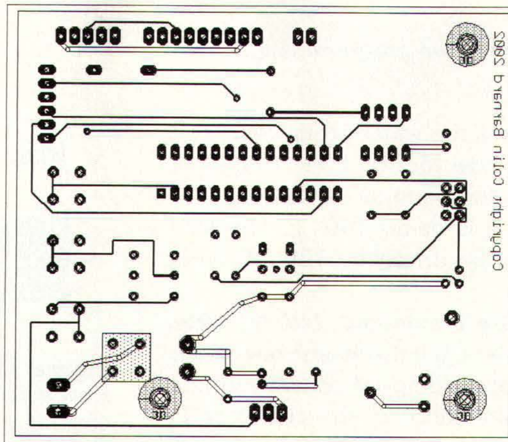


Figure 3b. PCB tracks lower side. **3.68" x 3.2"**

here has a flow rate of 1.5-30 liters/minute.

Electronics Construction

The PCB in Figure 3 is double-sided and is quite straightforward to populate. All the components with the exception of the LCD, D2, and R8 fit on the PCB. Start with the smallest components first. A narrow 28-pin socket is required for IC1 or use snap-off socket strips. The headers are snap-off SIL pin headers normally in strips of 25 or so. The push buttons can be soldered either to the PCB or be panel-mounted and have trailing wires attached to the PCB. The layout is not critical, so prototype perfboard could be used instead. Diode D2 is fitted directly across the solenoid terminals. JP3 is connected to the outside world via an eight-pin DIN socket.

It is suggested that eight core data cable is used for the external data connections.

The sensor requires R8 to be wired between its supply pin and the anode of the LED (pin 5 of the sensor). To connect the wiring to the sensor, the white cap needs to be pried off the sensor and a piece of 0.1" veroboard 4 x 9 holes can be placed neatly over the terminals and R8, and the wiring soldered to this.

When the board has been completed — but before IC1 and the display have been fitted — check for shorts and solder splashes. If all seems okay, connect to the power supply and check that 5V appears at the output of IC2 and at pin 20 of IC1. If all is well, disconnect the power and insert the PIC and connect the display — now we are ready to set up.

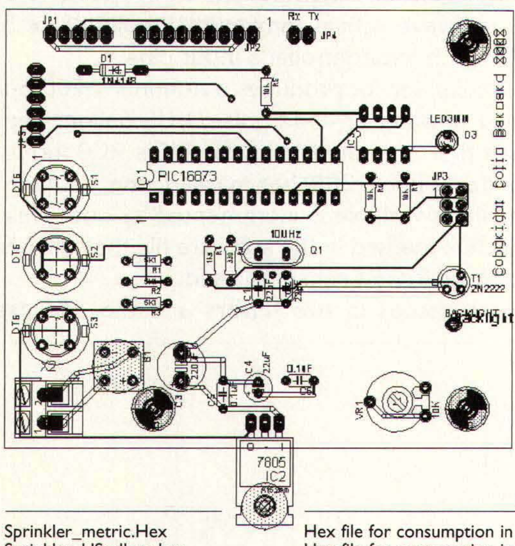


Figure 3c. Component layout, top of board.

Sprinkler_metric.Hex	Hex file for consumption in Liters
Sprinkler_USgallons.hex	Hex file for consumption in US Gallons
P16F877_2_INC.h	Header file to allow bit access of registers
Sprinkler.h	Main header file for project
ButtonPress.h	Header file for button routines
LCD_shiftout.h	Header file for display routine
Sprinkler.c	Main file
Lcd_1.c	LCD display file
sprinkler.fpd	Front panel design
Sprinkler.brd	PCB layout file

These files are available at www.nutsvolts.com

The Display in Event Setting Mode. Event No. 1 is shown with the Event Minutes having just been set to 15 minutes, and the event will happen at 9:15 every Monday morning.

Setting Up

Depending on the rise time of your programmer or power supply, the unit may start up in power disrupt mode. If so, just press the Menu key and the set-up menu will appear. The menu defaults to the setting of the current day, the next press of the Menu key will allow the current time to be entered — for accuracy, enter the minutes last as the seconds revert to zero at the release of button 3.

Sources

[1] Pre-programmed 16F873 US $8.65, PCB US $13.70 postage included available from Colin Barnard at (cdb@barnard.name). The 16F873 is also available from Digi-Key **www.digikey.com** or **www.crownhill.co.uk**.
[2] RS Components **www.rs-components.com**, Rapid Electronics **www.rapidelectronics.co.uk.**
[3] Wiz-C compiler **www.fored.co. uk/ www.dontronics.com.**

See Table 1 for the complete button action list. On the prototype with the solenoid and LED off, current consumption was 28mA rising to 240mA with the solenoid switched on.

Menu Button (S1)		Button 2 (S2) Action on Press	Button 3 (S3) Action on Press
Power Out Reset		No Action	No Action
Menu 0		View Cost and Usage information	Override Timer Event/Manual water on or off
Menu 1		Increment	
	0	Event Day	Next sub menu #1
	1	Event On Hour	Next sub menu #2
	2	Event On Minute	Next sub menu #3
	3	Hour Duration (max 4 hours)	Next sub menu #4
	4	MinsDuration (15 min intervals)	Next sub menu #5
	5	Next Event (Max 7)	Return to sub menu #0
Menu 2		Set Current Day	No Action
Menu 3		Set Current Hours	Set Current Minutes
Menu 4		Set Dollars/£ cost per unit	Set Cents/Pence cost per unit
Menu 5		Reset Gallons/Kliters	Reset Current Value Total

Table 1

Plumbing Construction

The flow sensor and solenoid have flow direction arrows marked on their bodies. The actual plumbing required will, of course, vary depending on individual requirements.

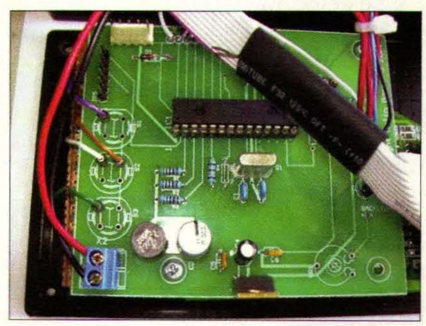
In the prototype, a standard hose tap adapter was connected to the solenoid which, in turn, was connected to a 1/2" to 1/2" female plastic adapter as the joiner to the flow sensor. From the flow sensor, a connector similar to a washing machine connector attaches to the hose pipe and is secured with a Jubilee clip. Don't forget to use plumbing tape on the threads to prevent leakages and — if possible — use brass fittings, as the plastic threads will stretch over time in hot weather! Naturally, the completed electronics shouldn't be allowed to come anywhere near water. A plastic case is necessary for the electronics and silicon sealant should be applied across the solenoid terminals and the exit hole for the flow sensor cable.

The Software

As mentioned previously, the software has been written in 'C.' This will be easy to convert to other versions of 'C' cross compilers for PICs. The files are well commented, and it will be easy to see where the alterations should be made for flow sensors with a different pulse count and changing the maximum and minimum on times and durations. It is not recommended to increase the number of events past eight unless one of the newer 18F252s or a step up to the 16F876 part is used, in which case, the 'C ' file will need to be recompiled.

If the project is only built as a usage meter or a more frequent write access is required, then an I2C EEPROM can be fitted with the required change to the software. Incidentally, there are 128 bytes of EEPROM space available and only nine bytes are presently used.

Special attention should be taken of the real-time clock (RTC) routine, which uses a rarely-used Bresenham algorithm for accuracy, no matter what crystal clock speed is chosen. Again, this is commented on in the file listing available for download at **www.nutsvolts.com.** **NV**



View of the button and power connections. The ISP connector is visible at the top of the board.

Resistors (1/4W, 5%)
R1, R2, R3 - 5.1K
R4 - 1.8K
R5, R6, R7 - 10K
R8 - 180 ohm (off board)
R9 - 330
VR1-10K Linear Preset

Semiconductors
D1 1N4148
D2 Diode Bridge W04G
D3 LED3MM
T1 2N2222A or equivalent
IC1 PIC 16F873/20MHz
IC2 7805 500mA TO220
X1 10MHz
LCD 2 x 16 with backlight
Flow Sensor part# RS 257-133
Solenoid part# RS 342-023
(From RS Components UK)

Capacitors (all except C8 2.5mm lead spacing)
C1, C2 - 22pF
C3 - 220uF/25V 8.5mm lead spacing
C4 - 22uF/10V
C5, C6-0.1uF

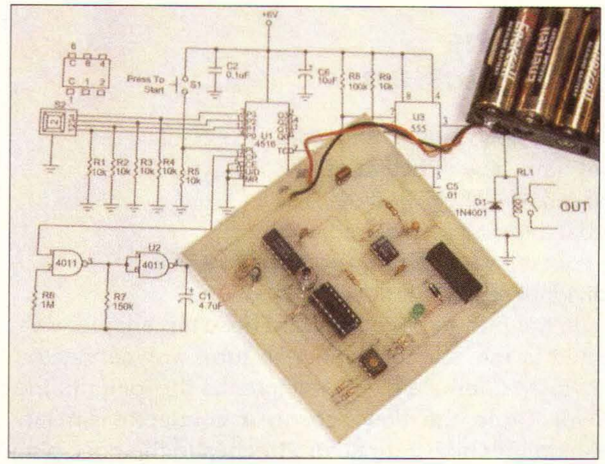
Miscellaneous
S1, S2, S3 Push-button switches momentary contact
DIL 8-pin IC socket (optional)
DIL 28-pin IC socket (narrow or IC strip)
JP1,2,4,5 Strip of pin headers
JP3 2 x 3 Strip of dual pin headers
X2 PCB mounting 2-way terminal block
DIN Socket 8-way or equivalent
DIN Plug 8-way or equivalent
Plastic Case 6 x 4 x 2" minimum
Cable 8 core capable of 0.4A min e.g., 7.0mm x 0.2mm conductors
Circuit Board

View of the solenoid (top) and flow sensor (bottom) in situ. The flyback diode board can just be seen in the background.

by TJ Byers

Build The Frat Chime

Construct this automated chime for your lodge or fraternity



There's a stillness in the air. Fixed eyes focus on a handsomely-crafted wall clock, some strain at dimly-lit wristwatches. The minute hand ticks ever closer to that Witching hour. Boing ... boing ... boing ... Let the ritual begin. Several "fraternal organizations" — like the Elks and Moose Lodge — use a chime, relating to a clock time, in various parts of their rituals. Traditionally, the chime was a small gong or bell tuned to a resonant frequency with pleasing overtones that rang out when struck by a wooden mallet. An assigned member of the fraternity was in charge of both timekeeping and the striking of the chime.

Each fraternity has a different day and a different hour for these rituals — a requirement that inspired this project — which I fondly call the Frat Chime. Press the Start button, and the Frat Chime produces a train of metered pulses that "sound" the chime for the number of times set by a selector switch. These pulses close a relay that actuates an electric chime or other announcer device.

How It Works

The circuit consists of three sections. Refer to Figure 1. The first and main section is a 4516 binary up/down counter (U1). This chip will either count up to a preset value, or count down from a preset value. I opted to use the count down mode simply because it kept things easier. Using this method, the numbers shown on the face of S2 equal the number of times the chime rings. If you set S2 to six, the chime will sound six times. The starting number is loaded into the counter when you push the Press To Start (S1) button.

This causes the carry output (pin 7) to go high and start a 1/2-Hz clock — one pulse every two seconds — made up of U2A and U2B. Each tick of the clock subtracts one from the total entered into the 4516 (this is done by consecutive pulses on CP, pin 15), until it reaches zero, at which time the carry out goes low and the clock ceases to tock. What this means is that if you enter the number 7 into the presets, then press S1, the clock will tick exactly seven times and then stop.

While all this is taking place, U2C and U2D — configured as a non-inverting

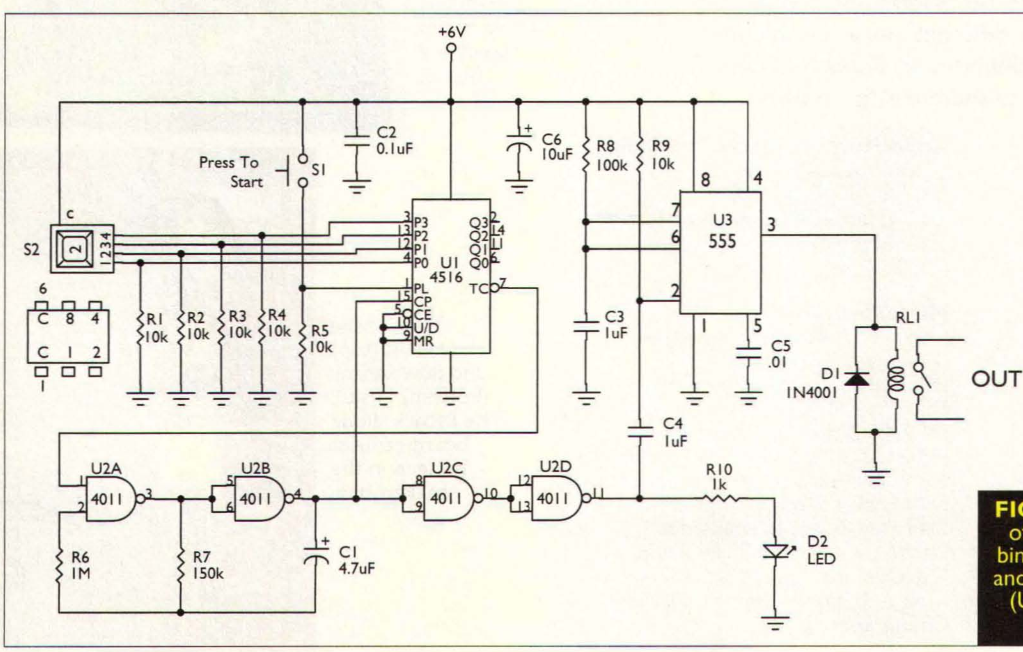


FIGURE 1. The Frat Chime consists of three sections: A programmable binary down counter made up of U1 and S2, a gated squarewave generator (U2A and U2B), and a monostable multivibrator (U3).

Parts List

Resistors
R1,R2,R3,R4,R5,R9 — 10k
R6 — 1 Meg
R7 — 150k
R8 — 100k
R10 — 1k

Capacitors
C1 — 4.7uF
C2 — 0.1uF
C3 — 1uF
C4 — .01uF
C5 — .01uF

Semiconductors
D1 — 1N4148
D2 — LED
U1 — 4516
U2 — 4011
U3 — 555

Misc.
S1 — Normally-open push-button switch
S2 — Hexdec rotary switch (Digi-Key SW217-ND or equivalent)
RL1 — 5V SPST, NO relay (Hamlin 3321A0400 or equivalent)
Battery holder — four 'AA' cells
6VDC wall-wart (optional)

An etched and drilled circuit board is available for $9.00 from Futurlec, 1133 Broadway, Suite 706, New York, NY 10010 (**www.futurlec.com**). A kit of the above parts is also available for $18.00 and includes an etched and drilled printed circuit board, batteries not included. Add $3.00 for shipping and handling.

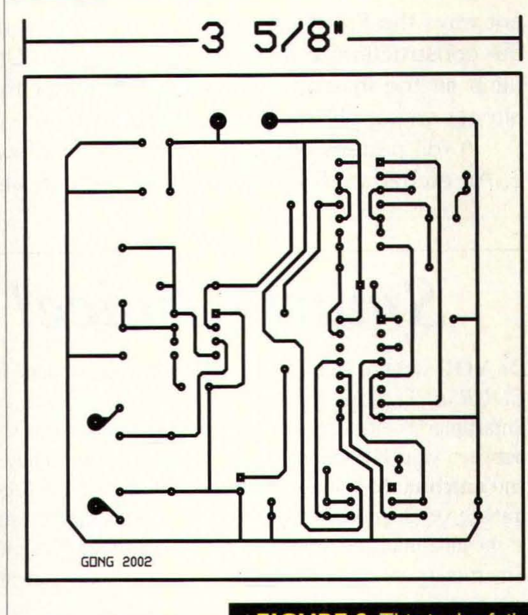


FIGURE 2. This is the foil pattern for the Frat Chime. An etched and drilled circuit board is available from Futurlec for $9.00. See the Parts List for details.

buffer — follow in sync and provide pulses to D2, a light-emitting diode, and U3 (via coupling capacitor C4). U3 is a monostable oscillator. Each time the input (pin 2) goes low, the 555 output (pin 3) will go high, which causes RL1 relay contacts to close for about one-half second. Resistor R8 and capacitor C3 determine the length of time the relay stays closed using the formula: $t = 1.1RC$, where R is in ohms and C is in farads.

I know this calculates to be longer than one-half second "on" time, but you have to remember that a relay is a mechanical device. That is, it takes time for the contacts to make contact. So while the metal arms are swinging into position, the 555's meter is running. When you add these numbers up, it means that the actual time the contacts are closed is the 555 time-out time minus the amount of time it takes for the relay contacts to engage. I point this out because if you substitute a different relay for the one specified, or replace it with an opto-coupler, you'll need to adjust the values of R8 and C3 accordingly.

Want a longer time between chimes? Increasing C1's value stretches it out, and decreasing it makes the strikes closer together.

All the reader needs is a soldering iron and soldering skills.

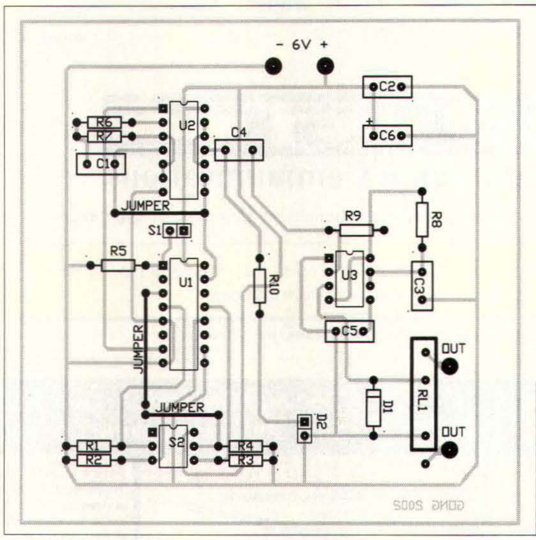


FIGURE 3. When placing the parts on the circuit board, observe IC orientation and capacitor polarity. Note that three jumpers are required.

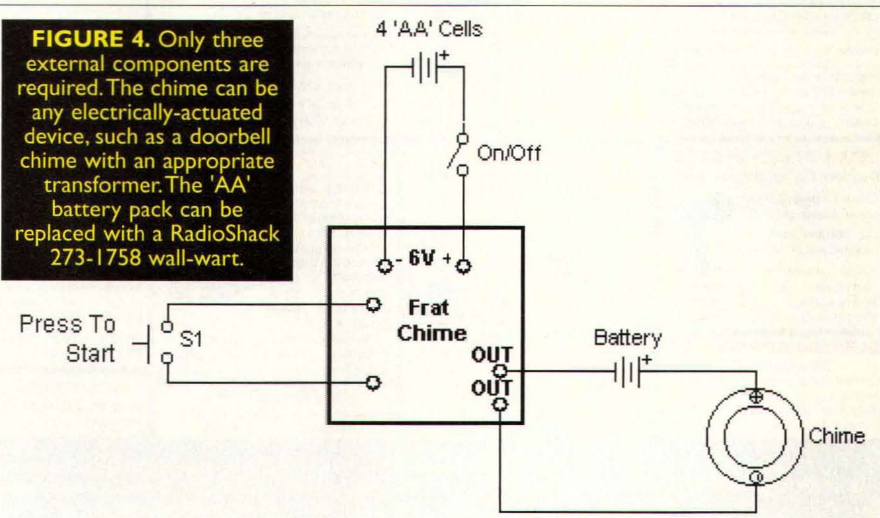


FIGURE 4. Only three external components are required. The chime can be any electrically-actuated device, such as a doorbell chime with an appropriate transformer. The 'AA' battery pack can be replaced with a RadioShack 273-1758 wall-wart.

Construction

Because there are so many different ways the Frat Chime can be used, I purposely limited the construction to a printed circuit board. One that contains all the ins-and-outs needed to adapt the design to almost any application. I leave the enclosure up to you.

A foil pattern of the circuit board is shown in Figure 2. An etched and drilled circuit board can be purchased from Futurlec for $9.00 (see Parts List). However, the circuit board isn't a must. The project can be constructed using any method you wish, including perfboard and wirewrap.

A parts placement guide is shown in Figure 3. Layout isn't critical, but you have to pay attention to the position of the ICs and SW2, and the polarity of capacitors C1 and C6. Also note that the board includes three jumper wires. I did this so that the circuit board can be made using single-sided clad, which is easier for the hobbyist to duplicate than a double-sided board.

I power my Frat Chime with four AA-cell batteries, but you can use a small six-volt wall-wart, like the RadioShack 273-1758. Like I said, I leave the mounting of the circuit board up to you simply because there are so many options.

For example, you may wish to install it into a project box, along with the chime, and run a pair of wires out to S1, the Press To Start button. Or maybe in the base of a lamp that flashes on and off to aid those with impaired hearing. The possibilities are endless. See Figure 4 for a typical example.

It's Time

After building the Frat Chime, I showed it to my girlfriend who laughed out loud at the idea — until she saw a use for it in the kitchen. She now uses it to time and count the number of strokes for cake mixes and other chores that used to be done by mumbling one Mississippi, two Mississippi, three ...

Uh-oh ... the clock just struck 13, which means I'm out of here! **NV**

Circle #75 on the Reader Service Card.

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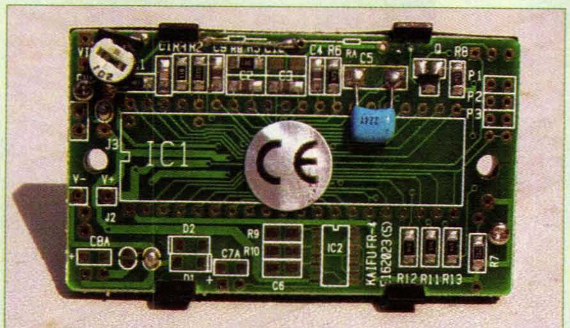
EXTENDING THE RANGE OF THE DIGITAL VOLTMETER MODULE

by David Ponting



The rear view of the PCB of the PM-128 digital voltmeter module.

Make your voltmeter measure up ...

There was a time when all panel meters were round. Then — as an aesthetic variation — square ones and rectangular ones were introduced. At this time, they all used a lightweight metallic needle which rotated about a fixed point across a printed scale. These pointers were usually driven by the magnetic interaction of a current-carrying coil of fine wire with a permanent magnet, and the whole moving assembly operated against the action of a return spring. Fundamentally, they all measured current flow and were accurate to no more than a handful of percentage points at best.

Both poor and good quality analog panel meters shared many disadvantages. First of all, the zero reading had to be set by carefully adjusting a small screw on the front of the meter. Periodic re-adjustment was sometimes needed, but re-setting was almost always a necessity when, having zeroed the meter for horizontal use, it was then moved into the vertical plane.

Second, estimating the position of the pointer was never simple. The needle rested above the surface of the scale so that unless your eye was directly above it, the reading could be recorded as higher or lower than it should be. On better meters, the scale included a mirror section so that you could line up the pointer with its reflection and avoid these parallax errors. In addition, higher quality meters had very long scales to improve their accuracy, but this also made them physically large.

Third, the meter's precision was always compromised by the resistance of the coil of fine wire. This caused a significant voltage drop when measuring current, and diverted current when measuring voltage. This meant that it was impossible to measure accurately very small values of either voltage or current. Further, a typical panel meter having an intended full scale deflection (FSD) of, say, 1mA might well have an internal resistance of 100 ohms. If it did, then the same full scale reading could also be interpreted as 1/10th volt. When you went shopping for them, the parameter "ohms per volt" was often attached to panel meters: the higher this figure was, then the more sensitive (and the more expensive) the meter. Fourth, analog panel meters were physically fragile.

And fifth, there was the ever present problem of accidental overload. A panel meter might very well tolerate a small excess of the order of 200%, but anything much greater than this and you would end up with a very bent needle wrapped around one of the meter's end-stops — or in the final analysis — with a burned out coil and a funny smell. Then along came the digital panel meter.

Fundamentally, these are designed to measure voltage. For a while they were somewhat expensive compared with

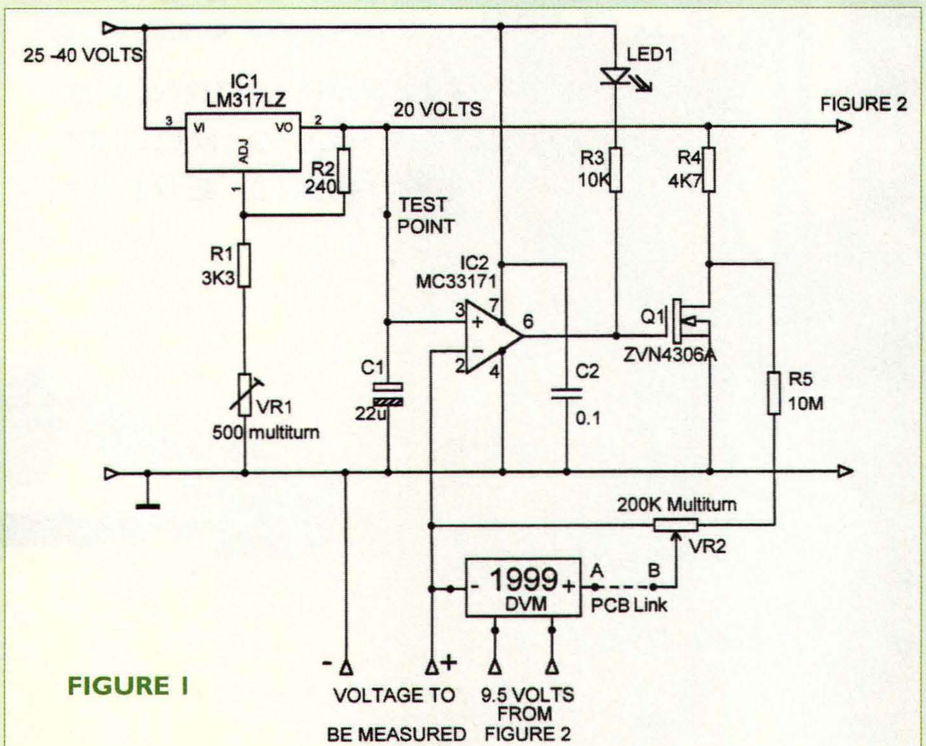


FIGURE 1

the analog version, but today, the ubiquitous, so-called 3-1/2 figure digital panel meter (that is one with a maximum numerical display of 1999) is probably as cheap as — if not cheaper than — its analog cousin.

Gone is the need to zero the digital voltmeter (DVM) since it is guaranteed to read 0000 for zero input and, of course, any measured voltage can be read directly in figures instead of trying to estimate the position of a needle. The digital meter's input impedance is greater than 100 megohms and its display is accurate to plus or minus half of one percent. Compared with an analog panel meter, the digital version is very robust and more or less impervious to a wide range of both positive and negative overloads. If the input signal lies outside the digital meter's display range, a single '1' appears in the display to indicate this condition. You might think that with all these advantages over the moving coil panel meter, the digital version must be the perfect alternative. However, it has three major drawbacks which this article tries to address. Two of these problems are concerned with scaling.

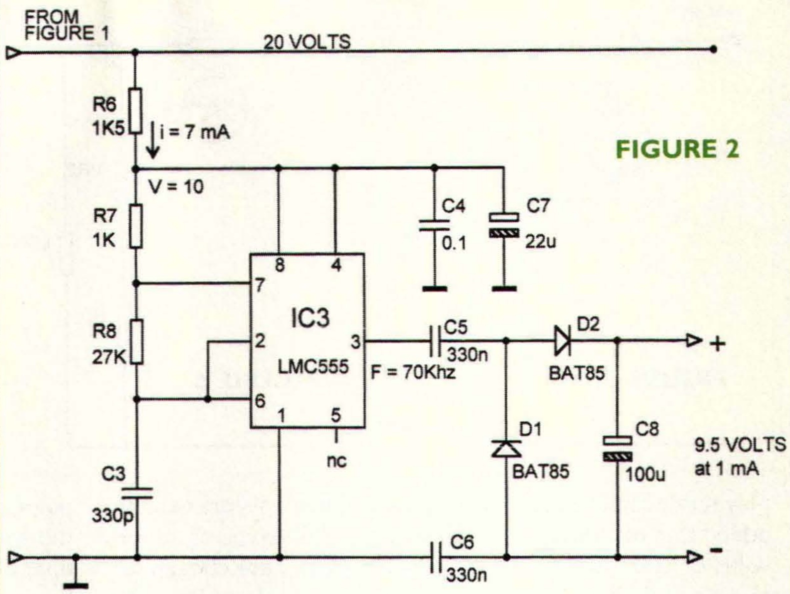


FIGURE 2

First, the real advantage of the high-input impedance of the digital voltmeter can itself be a problem when it comes to changing the scale. The instruction leaflet which came with the PM-128 digital panel meter I was experimenting with suggests that to change the scale from the fundamental of 200mV (actually 199.9mV) to a full scale deflection of 200V (199.9V), you disconnect a wire link which bridges pads marked RB at the top of the meter's PCB and replace it with a resistor of 9.99 megohms. Another resistor of 10K ohms is then soldered into a second position marked RA along the same edge of the PCB. It suggests that both resistors should be 0.5 percent types.

The digital panel meter's supplier was telephoned and asked where they bought their half percent, 9.99 megohm resistors and their suggestion was: "Use a 10 meg resistor and take up the slack by adjusting the existing trim potentiometer on the PCB." However, when this was tried, the potentiometer seemed to have insufficient range to accommodate the tolerances of the two resistors used, even though both the 10K (one percent) and the 10 megohm resistors had been accurately measured before selection.

Further, if the DVM is to be used over a number of ranges, the on-board trim potentiometer would have to be adjusted each time the range was changed. Consequently, a more certain solution was sought and the first circuit described includes voltage dividing resistors which corrects this problem.

The second scaling problem has no solution in a general sense. With the old style analog panel meter set up with appropriately-chosen resistors, the input could be proportioned to give a full scale deflection of any value of voltage or current. Low resistance shunts straight across its terminals would allow it to read large currents, while adding potential dividing resistors would make it suitable for registering high voltages. Of course, this is similar, but not the same for the digital meter. The difference is that the analog panel meters can have a full range of any value, for example 42 volts if required, and then it would be a relatively simple matter to replace the 0-100 printed scale with one marked 0-42. But that can never be done with a digital meter. However its input is scaled, the maximum reading is always going to dis-

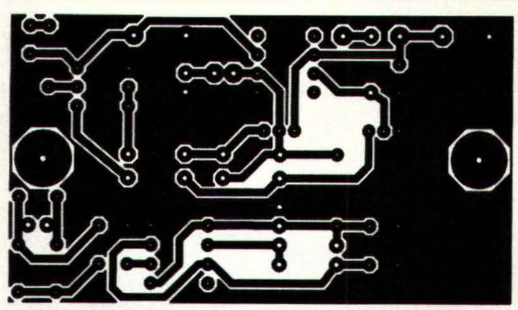
FIGURE 3A


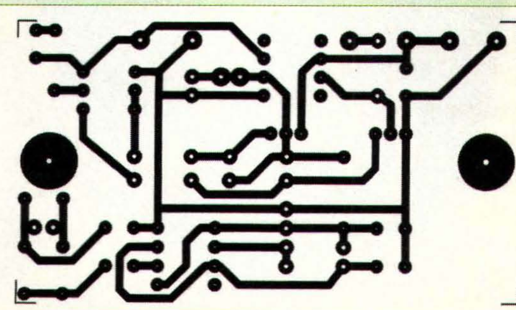
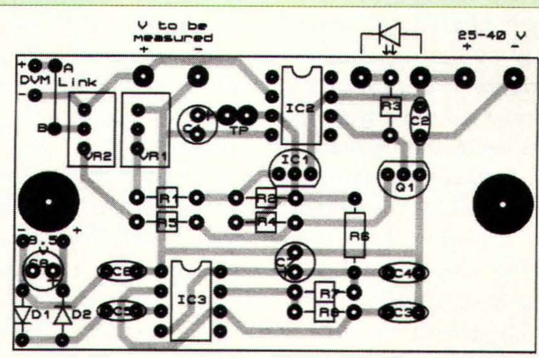
FIGURE 3B


FIGURE 4


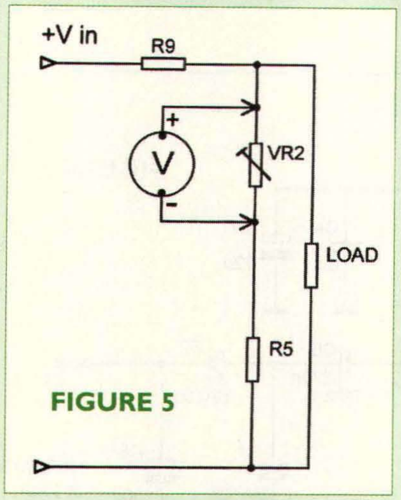


FIGURE 5

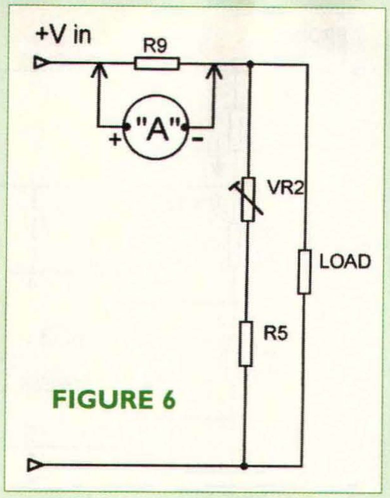
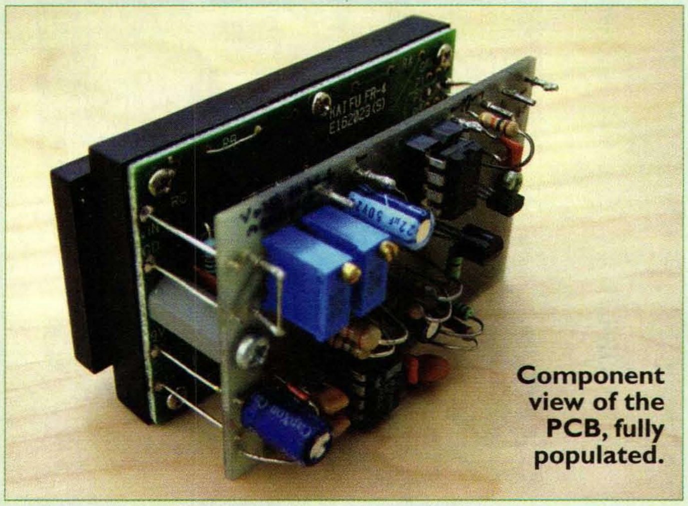


FIGURE 6

play numerically as 1999 which means that resistors can be added to make its full scale deflection 1.999 volts, or 19.99 volts, or 199.9 volts, or more, but if resistors are chosen to make the FSD an input of 42 volts, the digital reading will still be 1999.

This is not much of a problem if you are happy to keep changing the meter's fundamental scale by factors of 10, but scaling up in this way results at each step in a corresponding loss of accuracy by the same factor of 10. This really hit home when I was making a bench-type, variable DC power supply and I wanted to incorporate a digital panel meter to allow an accurate setting of the output voltage being applied to the load. The unit planned was designed to supply a maximum output of 35 volts at a maximum current of two amps. With this voltage measurement requirement, there were two choices: either measure voltages up to 19.99 on one scale and then manually switch to the 199.9 scale for 20 to 35 volts (which is inconvenient and results in a lower accuracy on the higher range) or measure everything on the 199.9-volt scale and accept that this reduces the precision to one decimal place on all readings.

Using a digital panel meter with a 3-3/4 scale to read up to 3999 is the obvious solution, but inexpensive ones simply aren't available. However, Figure 1 shows the circuit diagram for a very simple design which effectively makes a 19.99 digital voltmeter read up to 39.99 with an accuracy close to 1/100th volt across the entire range. Because this circuit was designed for use with the bench power supply being built, it is referred to in that connection. However, with minimal changes, a fully stand-alone 3999 DVM-equivalent can be built.



Component view of the PCB, fully populated.

In the circuit diagram, consider first the range of the DVM module. Using the scaling resistor R5 which has a marked value of 10 megohms, and with multi-turn potentiometer VR2 properly adjusted, the DVM can be set to measure up to 19.99 volts. The position of the decimal point is controlled from a matrix of six solder pads at the top right corner on the rear of the DVM's PCB. The three rows are marked P1, P2, and P3. Note that the three pads in the right-hand column are all commoned. Connecting the two pads together in the top row marked P1 will light the decimal point at 000.0. Similarly, shorting the pair of pads in the row marked P2 will display the decimal point in the second position: 00.00. And for P3, we get 0.000. For the purposes of this circuit, the P2 pair should be shorted to obtain the decimal point position as 00.00.

Returning to the circuit in Figure 1, the power supply of 25 to 40 volts shown does not itself need to be regulated, but should be at least three volts or so greater than the highest voltage to be measured. For the bench power supply I was building, voltages up to 35 were to be provided and, conveniently, an approximate 40-volt source was already available. This is the same supply that would subsequently be regulated, made variable, and then used for the bench power unit's output of up to 35 volts at two amps.

IC1 is an LM317LZ variable voltage regulator. The TO 92, 100 mA type is recommended over its bigger brothers because it provides much better line regulation than all the other versions. This voltage regulator with R1, R2, and VR1 is adjusted to provide a stable output at pin 2 of 20 volts which is applied directly to the non-inverting input of op-amp IC2. C1 eliminates any high-frequency jitter which might otherwise appear on this line. The supply voltage for the op-amp is taken from the un-regulated input and decoupled by C2. The negative side of the voltage to be measured is connected to common ground while the positive side is applied directly to the inverting input of IC2.

Configured in this way, the op-amp is being used as a voltage comparator and so its output at pin 6 is high when the voltage at pin 3 is smaller than that at pin 2, and is low when pin 2 is greater than pin 3. Consequently, with pin 3 pre-set at 20 volts, the op-amp's output is high when the voltage being measured is less than 20. Under these conditions, LED1 is not lit, but the MOSFET Q1 is switched on hard so that the "north" end of R5 is effectively joined to ground. The DVM module with its scaling resistors is now connected directly across the voltage being measured and this value can be read off the display.

However, when the voltage to be measured is greater than 20 volts, the output of IC2 is switched low, LED1 lights and with Q1 off, the "north" end of R5 is connected via R4 to the 20-volt output of IC1. Under these conditions, one side of the DVM's scaling resistor R5 is sitting at a potential of 20 volts above common negative and the DVM module will now read the potential difference between the voltage being measured and 20; the lit LED is an indication that 20 volts must now be added to the reading on the display. R4 is a current-limiting load resistor which prevents a dead short across the 20-volt line when Q1 is fully on; its value of 4K7 is insignificant compared with the 10 megohms of R5.

All that may sound a little complicated but, in practice, the circuit is easy to make, set up, and use. The third problem when using digital panel meters is that most require an entirely independent and floating power supply of 7 to 11 volts. This usually means running the meter from a nine-volt battery (which, of course, is always flat at the moment it is needed) or involves an extra winding on the mains transformer together with separate rectification and smoothing. What you cannot normally do is directly employ any higher voltage already being used for the main power source as the supply for the DVM module. However, Figure 2 shows an easy way of doing just that.

The 20-volt line in Figure 2 is taken directly from the output of the LM317LZ in Figure 1. R6 drops about 10 volts and the remainder (decoupled by C4 and C7) powers IC3, the CMOS version of the standard 555 timer chip. This IC is configured as an oscillator with R7, R8, and C3 determining the output frequency of around 70 kHz. As the value of R8 is much greater than R7, the duty cycle of the squarewave output at pin 3 is almost 50% and, by using the CMOS version of the 555, it is virtually rail-to-rail. C5 and C6 provide DC isolation from the rest of the circuit while Schottky diodes D1 and D2 rectify and almost double the output with minimum losses. C8 provides the necessary smoothing. With the component values shown in the diagram, the output has a floating value of about 9-1/2 volts and will more than adequately supply the 1 mA of current necessary to drive the DVM module.

Figure 3A and 3B are full-size positives of the single copper side of a printed circuit board which will accommodate the circuits of both Figures 1 and 2. The 3A illustration represents the preferred version of the PCB which uses a fill ground plane, while the 3B version has all the earth connections of components joined by tracking, allowing easier manufacture for those who prefer to make their own boards. Figure 4 shows the placement of components when either version of the PCB is used.

Populating the board with its components should present few difficulties. All the components are pretty standard with the exception perhaps of the op-amp. The recommended one is an MC33171 which, nevertheless, is readily available from component suppliers and has been chosen both because it is particularly suitable for single rail use, but also because it will allow a power supply of up to 44 volts. For more modest requirements where this supply can be kept to a maximum of 36 volts, the ubiquitous 741 device will serve almost as well, although the MC33171 provides a closer rail-to-rail output compared with the 741. The MOSFET ZVN4306A is the recommended type for Q1 mainly because of its small ON resistance. Data sheets show this to be only 0.45 ohms, a value which — in this circuit — results in an error in the measured voltage of only about 1/2 mV when the MOSFET is full on.

Before the trim pots are fitted, their resistance should be measured and they should be set at their central positions before being soldered in place. It is also good practice to fit the two, eight-pin ICs into DIL sockets so that these ICs can be easily exchanged, if necessary. The LMC555 (or 7555) timer IC is a CMOS device and this, together with the MOSFET, should be handled as little as possible.

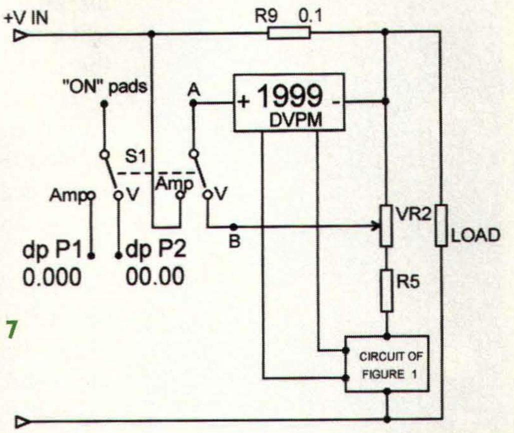


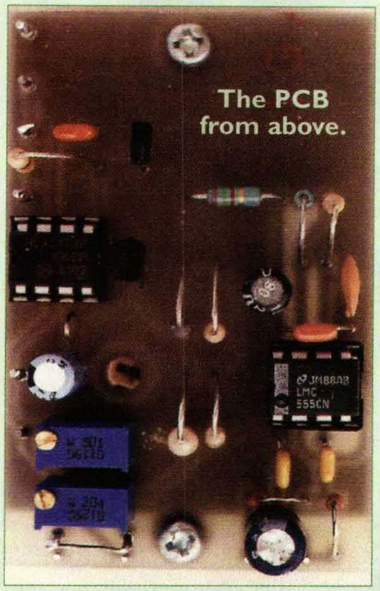
FIGURE 7

SETTING UP

When the printed circuit board has been completed (not forgetting the wire link), it should be connected to a 25- to 40-volt supply and checked that there is no excessive current flow which could indicate track shorts. The power lines to the IC sockets should be voltage-tested and assuming that all is well, the op-amp and timer ICs should be fitted and the LED tacked to its pins on the PCB, which can be temporarily loose-wired to the DVM module.

To set up the circuit, an accurate multimeter and a variable voltage source are needed. If necessary, the latter can simply be created using the existing 25 to 40 volts to feed a breadboard set-up of another LM317 with its own 240-ohm resistor and a 5K pot to ground. This source is connected to the "voltage to be measured" pins and should be set at about 19 volts as measured on the multimeter. At this time, there should be a reading of some kind on the DVM module and trim pot VR2 must be adjusted until the module and the multimeter read precisely the same. The multimeter should then be connected between the test point and earth, and VR1 adjusted until the meter reads a precise 20.00 volts. The variable voltage source can then be used to check that voltages below 20 are accurately recorded directly on the DVM mod-

The PCB piggybacked onto the PM-128.


The PCB from above.

ule and, as the 20-volt watershed is passed, the LED lights and the DVM returns to a zero count before continuing to read the voltage differences above 20. That is all the setting-up there is.

The now-completed PCB is exactly the same size as the DVM and it can be directly fitted to the module using M3 spacers and screws through the two holes at the edges of the PCB. With the two boards piggybacked together, two pairs of solder pads at the left hand edges of both PCBs will line up and these can now be linked across by four short lengths of wire. (The complete project in Photo 2 shows my prototype version where the four linking wires are in slightly different positions from those shown in the PCB template. The form of the PCB published in this article conforms exactly to the new version of the PM-128 modules currently available.)

Once this assembly has been completed, it is worth repeating the whole set-up procedure a couple of times and, in any case, before final calibration, the unit should be switched on and left for five minutes or so to allow it thoroughly to warm up and stabilize. Each time the unit is used, readings may drift upwards slightly for the first few seconds until it is again properly warmed up.

Looking once more at Figure 1, it may appear that the meter module is wrongly connected with its positive and negative inputs reversed. However, while experimenting with the DVM, it may be noticed that it will read the same numerical value when a voltage is applied with its input leads connected either way round. In other words, this module has yet another feature: it can also be used as a "center zero" meter! Unfortunately for our purposes, the un-modified DVM module will display voltages with a negative sign. However, a further link solder on the PCB of the DVM module will correct this. Referring back to the 2 by 3 decimal-point matrix in the top right corner of the PM-128 module, a fourth row of solder pads can be seen. The two immediately below the matrix are already joined, but if one of these is linked to the tiny pad in the same row and immediately below P3, the negative sign in the display can be turned off.

In the circuit in Figure 1, it is important that the DVM module is connected with its more negative input joined to the positive side of the voltage to be measured. This configuration results in readings which are very stable. Reversing the connections tends to make the high resistance of R5 something of a hum detector and readings are prone to jitter. In any case, using the DVM module for the bench supply and wiring it in this "reversed" way, provided yet another opportunity. Figure 5 shows how voltage applied to a load is normally measured when a DC supply is being used. R9 — in this diagram — is a current-sensing, low-value, high-wattage resistor. Load voltage measurement must be downstream of this resistor or the potential drop across it will result in significant errors in the display. A voltmeter with its plus and minus connections as shown, measures the voltage across the smaller of two proportioning resistors.

Figure 6 shows how R9 can be used with a voltmeter to measure the current being supplied to the load. There will be a voltage drop across R9 which is proportional to the current flowing through it. This means that the voltage to the "west" of this resistor is greater than that to the "east," and so the voltmeter needs to be connected with its positive and negative inputs as shown.

From Figures 5 and 6 together, it can be seen that if a single meter is to be used for both voltage and current measurements, each of the meter's input leads needs to be switched so that current flow through the meter is always in the correct direction. This means that a rare, three-pole change-over switch is normally required, as the decimal points on the current and voltage scales will be in different positions and also need to be reconnected. However, the PM-128 DVM is bi-directional and Figure 7 shows how only the module's positive lead needs to be switched, leaving the second pole of the same switch to deal with the decimal points.

And finally, the maximum load current in the bench supply is to be two amps and the fundamental FSD of the DVM is 200 mV, so Ohm's Law would suggest that R9 should be 0.1 ohms. By choosing the position of the decimal point as 0.000 for current measurement, the voltage reading on the DVM will represent in amps the load current flowing. Because of non-load current flowing through the proportioning resistors R5 and VR2, there will be a very small error in current measurement, but this amounts to a maximum of only about 3-1/2 microamps.

On the printed circuit board for this project, there is one link. If the DVM with its extended range PCB is to be used for measuring both voltage and current as described, this link can be removed and points A and B joined to the appropriate tags on the two-pole, change-over switch, S1. **NV**

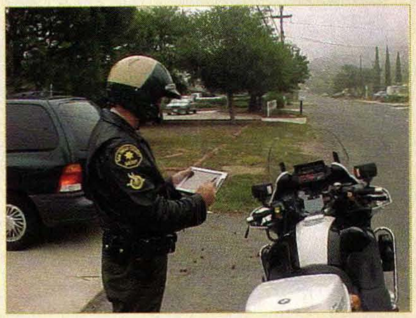
PARTS LIST

Resistors:	(all 5%, 1/4 watt unless marked)	IC3	LMC555 (7555)
R1	3K3	Q1	ZVN4306A MOSFET
R2	240		
R3	10K		
R4	4K7	D1, 2	BAT85, Schottky
R5	10M		
R6	1K5	LED1	High intensity, low current
R7	1K		
R8	27K		
R9	0.1, 1%, 1 watt	**Capacitors:**	
		C1	22uF, 25V
VR1	500 multi-turn	C2, 4	0.1uF
VR2	200K multi-turn	C3	330pF
		C5, 6	330nF
Semiconductors:		C7	22uF, 16V
IC1	LM317LZ variable volt. reg.	C8	100uF, 16V
		Miscellaneous:	
IC2	MC33171 op-amp	S1	2PDT switch
		DVM module	PM-128

High-Tech Cop Cars and Motorcycles

by Bill Siuru

Get up-to-date on the latest wireless communications and computer technology that police departments are utilizing.



San Diego County Deputy Sheriff Joe Dean using the Panasonic Mobile Data Wireless Display (MDWD).

Once upon a time, when a policeman wanted to talk to headquarters, he had to find a pay phone. If headquarters, wanted to talk to him, they would call someone who had a telephone, who would post some type of signal in a designated location. Seeing the signal, the cop would drive to the nearest pay phone and call in. Two-way radios in police cars that first appeared in the 1920s brought a major improvement in communication in the law-enforcement community. Today, cop cars and even cop motorcycles feature the latest wireless communications and computer technology.

Panasonic Toughbook CF-34 mounted in a protective case on the motorcycle.

Panasonic MDWD mounted on the handlebars of a San Diego County Sheriff Department's motorcycle.

TACHNET®

The cockpit of the typical police car today usually contains a laptop computer, one or more radios, video cameras, radars, as well as many switches for lights, sirens, and loudspeakers. Usually they are installed in a rather hodgepodge fashion, meaning less than optimum officer safety, efficiency, and ability to communicate. Officers often have to take their hands off the wheel and their eyes off the road to operate the dials and switches or view displays. Additionally, the National Center for Statistics and Analysis's Special Crash Investigations Program found several cases where the "flying" laptops injured the police officers in accidents. Other independent studies have shown installed equipment can interfere with air-bag deployment.

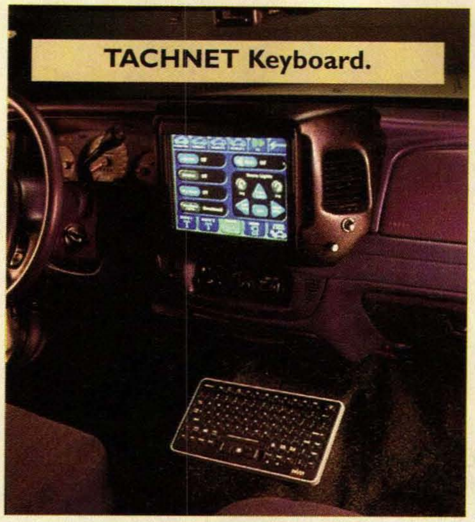
TACHNET Heads-Up Display.

Visteon Corp. has developed TACHNET® to greatly improve equipment interoperability, reduce cockpit clutter, enhance efficiency, and increase officer safety.

TACHNET — featuring a single command-and-control module — dramatically reduces the number of individual devices installed in a police car. The system integrates lights, siren, radios, radar, patrol video, and AM/FM radio functions onto a centralized in-dash control screen. TACHNET also allows simultaneous transmission over multiple radios and prioritizes radio signals allowing agencies to communicate with each other, while reducing the number of individual radios.

TACHNET uses three state-of-the-art technologies: a heads-up display or HUD, voice control, and a control pod for mission critical functions. This ergonomically-designed control pod is mounted at seat-level to provide intuitive fingertip control of siren, lights, emergency officer notification, and radio controls.

TACHNET uses two computers: one for critical functions like radios, lights, and sirens, and a 700 MHz Intel Celeron, with a 40GB hard drive for other data-driven applications such as doing reports.



TACHNET Keyboard.

TACHNET Hand Control Pod.

Finally, TACHNET's design removes objects from the air bag deployment path and minimizes the potential for equipment to become projectiles during a crash.

TACHNET was developed using technology provided through alliances with the leading and most-experienced vendors of hardware and software for the law-enforcement community.

These included Aether Systems, Federal Signal, Padcom, Kustom Signal, M/A-Com, Code 3, and Kenwood. Assistance was also provided by the Michigan State Police and Boston Police Department. In addition, TACHNET's open architecture allows plug-and-play expansion capability for easy upgrades as new technology comes along.

TACHNET uses Aether Systems' PacketCluster® Patrol™ software that is combined with Visteon's Voice Technology™ . So, for example, officers can query the National Crime Information Center (NCIC) via voice control with the results projected on the HUD. Currently, over 60,000 law-enforcement professionals use PacketCluster for applications ranging from real-time data access that results in increased returns on the number of stolen vehicles identified, to "silent dispatch" communication that allows dispatchers to spend more time on the most important tasks. In addition, wireless field reporting offered by the software optimizes the amount of time officers can spend on the streets.

Padcom, Inc., Wireless Data Connectivity Suite™ provides TACHNET's seamless and transparent wireless data communication. Padcom's modular software platform enables officers to access important information without worrying about which network is in coverage, improving both communication efficiency and safety for officers. The Connectivity Suite also provides greater control for network administrators and simplifies information flow for officers in the field, in addition to its software.

Federal Signal integrated several of its audible and visual warning products into the TACHNET system. These included: corner strobes with a programmable six-head power supply; numerous Generation III LED modules mounted both in and outside with an LED flasher to synchronize flashes; speakers and siren controllers; and low-profile all-LED "Arjent" lightbars. M/A-Com supplies the radio technology to enable integrated communications for TACHNET and provides a pathway to integrated voice and data communications over IP networks.

Padcom

The police car pulls into a parking lot. Virtually instantaneously, the computer in the squad-car downloads large data files with up-to-the-minute mugshot images, detailed crime reports, and other information needed immediately. The officer does not have to do anything other than drive to within the 300- to 500-foot service radius of parking lot access points since the connection and data download is totally automatic and transparent.

This capability comes from Padcom's TotalRoam Ellipse™ software and XcelleNet's Afaria, which provide high-speed access to large data files through a wireless LAN (local area network) installed in parking lots. When a patrol car fitted with the system enters the wireless LAN service area, TotalRoam Ellipse automatically connects. This wireless system replaces a previously used RF (radio frequency) infrastructure which lacked high-speed transfer capacity. Because of lack of bandwidth, sending a large graphic file like a mugshot could tie up the network for as long as an hour.

TotalRoam Ellipse uses an Internet Protocol (IP) standard for communication. By making use of the existing proprietary network, TotalRoam Ellipse software allows officers to transmit IP data over the Motorola RD-LAP network. Upon entering any of the 802.11 coverage areas, the wireless LAN capabilities of the TotalRoam Ellipse software, including the Afaria application, are automatically initiated, enabling officers to begin large file downloads through the wireless LAN. If officers must leave the LAN service zone before a download is complete, the system marks the point of interruption and then delivers remaining data when the car returns to any of the LAN-served parking lots.

Laptops for Motorcycle Cops

Laptop computers installed in police vehicles now routinely give law-enforcement officers immediate access to databases containing the latest information on wanted criminals, outstanding warrants, stolen vehicles, missing children, etc. Working with the San Diego County Sheriff's Department, CDGE, Inc. (in Yorba Linda, CA) has developed the same capability for motorcycle cops. Exposed to the elements and a motorcycle's vibration, this is a much more demanding environment. The system consists of a ruggedized Panasonic Toughbook computer mated to a Panasonic Mobile Data Wireless Display (MDWD). The MDWD features an 8.4-inch SVGA touch screen so data can be entered or retrieved without the use of a keyboard.

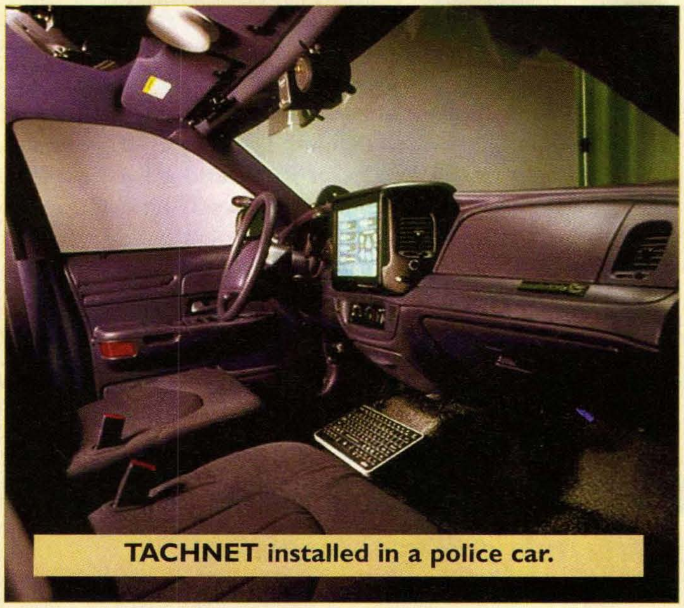
In the near future, the system will include voice recognition so deputies can give commands via the helmet microphone. Deputy Sheriff Joe Dean, who is heading up the project, says the screen works great, getting brighter in sun without a control switch, but the viewing angle does makes a difference.

The MDWD can be used with several wireless-enabled Toughbooks. These include the Toughbook CF-34, which was originally tested by the SD Sheriff's Department over a two-year period; the police standard CF-28; and the latest unit, the Toughbook CF-07 Mini PC, which is about the size of a brick, but weighs only two pounds. The CF-07 is more easily mounted on the motorcycle. The larger CD-34 was located in the side bag on the Harley-Davidson and Kawasaki motorcycles, and in the radio case on the BMW police bike.

When officers stop a vehicle, they can take the 1.5-pound MDWD — which is mounted on the motorcycle's handlebars in front of the officer — to the driver's window while leaving the PC on the motorcycle. This means the officer does not have to walk back to his motorcycle to access a computer database during traffic stops. The MDWD communicates with the Toughbook computer via a broadband wireless system for distances of up to 300 feet.

The computer communicates with the department's main computer system using a wide-area wireless network (WAN). Besides being able to check driver status and other information, the system means the officer's report is entered into the police department database in real-time, making the information on that person available to other officers who might encounter that driver later in the same day. Also in the works is an electronic ticket writing system.

The handheld-sized Pentium III-based CF-07 with a 300 MHz processor, 64 Mbytes of RAM, and a five-Gbyte hard drive uses a full version of the Windows 32-bit platform. This provides a richer platform for developers to add new applications. The equipment has been ruggedized for use in the motorcycle environment. This means being able to handle



TACHNET installed in a police car.

extreme weather conditions, as well as dropping the vibration of a motorcycle, and even liquid spills.

Automatic Crash Notification

Law-enforcement vehicles are involved in a higher percentage of crashes than other vehicles. Therefore, Ford is currently testing its new Automatic Crash Notification (ACN) technology in 500 Crown Victoria police cars in Houston, TX. Minutes can make the difference between life and death after a crash.

For example, 30 percent of deaths occur within minutes of the crash and 70 percent occur within two hours. All too often, the victims are not able to call for help. If the accident occurs in an isolated location, precious minutes are lost until someone comes upon the accident and calls for help. Automatic Crash Notification not only immediately notifies about an accident, but also reports on the severity of the accident so the appropriate life-saving staff and equipment can be dispatched, prepared to administer the proper medical assistance.

Ford's ACN uses a tri-axial accelerometer to measure acceleration and deceleration forces in all three planes to determine the force of a crash. Extreme changes in g-forces during a crash activate the system. Seat occupant sensors — contained in a woven mat placed under each seat — determine which seats are occupied by measuring changes in the electric field when someone is in the seat. Seat-belt usage is determined by buckle switch sensors in each belt.

Deceleration force magnitude and direction, air-bag deployment, number of occupants, and seat-belt usage are important factors in determining the severity of the accident and possible injuries. An on-board microprocessor compiles data to compute an accurate "picture" of the crash to help prepare trauma workers so they can more quickly diagnose and treat the injuries they are likely to see when they reach the crash scene.

Since accurate location information is critical when the crashed vehicle comes to rest in an area that is hidden from view, a GPS receiver and sensors determine both the vehicle's location and direction of travel at the time of the crash.

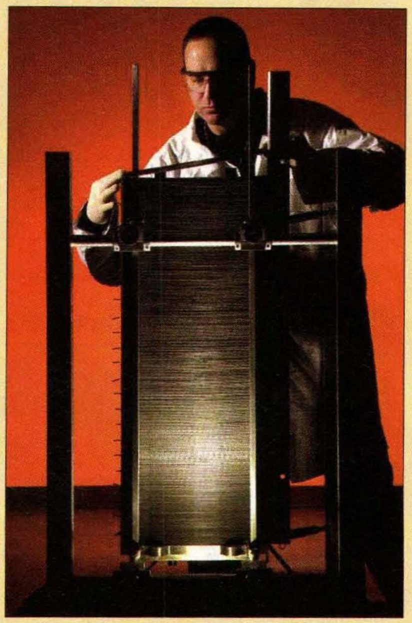
The dispatcher can query the occupants on their condition via a voice link. If the occupants are unable to respond, the operator still has critical data available to provide to the EMS responder, thereby establishing a quicker link to medical services. An independent power supply assures that all components still function should the vehicle's battery be damaged.

In this two-year long pilot project, emergency calls and sensor data are automatically transmitted by a wireless link to a call center operated by Cross Country Automotive Services. In turn, the information is automatically transmitted to the Greater Harris County's 9-1-1 Emergency Network. The car's occupants — in this case, the police officers — do not need to take any action for the link to be created. **NV**

Fuel Cell Facility Model for Hobbyists

by George Furukawa

Fuel cells offer an alternative technology for hobbyists.



Stacked fuel cells.
Courtesy of UTC Fuel Cells.

Perhaps in 30 years, we'll live in a world where fuel-cell-powered vehicles have replaced gas and diesel engine vehicles (fuel-cell-powered buses are already a reality in some cities in the United States). It may not be farfetched to also imagine living in a world where fuel cells power laptop computers and cellular phones.

What about a world where fuel cell generator systems power homes — or large fuel cells have replaced conventional combustion power plants? Have these predictions been snatched from the visionary works of Jules Verne and H.G. Wells? Are fuel cells science fiction or science fact?

According to experts in the field, fuel cell technology is science fact. The Hawaii Natural Energy Institute (HNEI) at the University of Hawaii (Manoa) campus was created in 1974 by the Hawaii Legislature in response to the first oil crisis in the world. HNEI is seeking new forms of energy to replace America's dependence on fossil fuels, and its mandate is to undertake and coordinate research and development of Hawaii's renewable energy resources.

Among other achievements, HNEI has spearheaded the discovery and use of geothermal power in Hawaii, coordinated the first comprehensive wind surveys of Hawaiian archipelago that furnished the data needed for installing wind turbines, conducted surveys of solar insulation and testing a variety of electricity-generating solar devices and systems, conducted major studies on ocean thermal energy conversion, developed the technology to use biomass for energy, charcoal, and high-value chemicals, and tested biomass-derived fuels as a replacement for conventional transportation fuels.

The Hawaii Fuel Cell Test Facility is a cooperative program of HNEI, UTC Fuel Cells, the United States Dept. of Defense's Office of Naval Research (ONR), and the Hawaiian Electric Company (HECO). Primary funding is provided by the Hawaii Energy and Environmental Technology (HEET) Initiative, a multi-million dollar program funded through ONR.

The facility is located in downtown Honolulu, and is currently under construction. It will house eight test stations to evaluate and characterize full-size, single-cell fuel cells. HNEI wants to develop improved membrane electrode assemblies, with emphasis on low-cost, efficient, impurity-tolerant, non-noble catalysts.

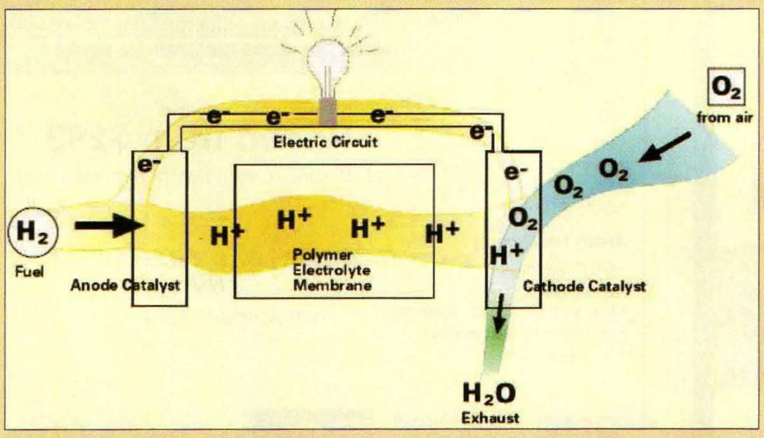


Diagram of a fuel cell. Fuel cells combine hydrogen and oxygen electrochemically to generate electricity. The only by-products are water and useful heat. *Courtesy of the US Dept. of Energy.*

HNEI also wants to develop optimal operating protocols for commercial and military applications using an integrated program of testing and modeling. Further research may include stack testing, other technologies such as solid oxide fuel cells, and testing of complete fuel cell systems.

HNEI and its partners will characterize the performance and reliability of fuel cells using test stands designed by UTC Fuel Cells — the company is supplying full-size fuel cells for testing. Stuart Energy is providing an electrolyzer to supply hydrogen gas on-site and on-demand. The first stand has been delivered, and two more stands were projected to arrive by the end of 2002. The facility is expected to be operational within the next few months.

So, what are fuel cells, and how do they work?

One of UTC's PC25 200-kilowatt power stacking. The graphic on the front of the power plant shows how it works.

Courtesy of UTC Fuel Cells.

Fuel cells produce electricity through the electrochemical reaction of hydrogen and oxygen. They enjoy higher efficiencies than internal combustion engines, produce little or no emissions, offer fuel flexibility, and generate little noise. Hydrogen fuel cells hold promise as a source of energy for electricity generation, transportation, and other applications.

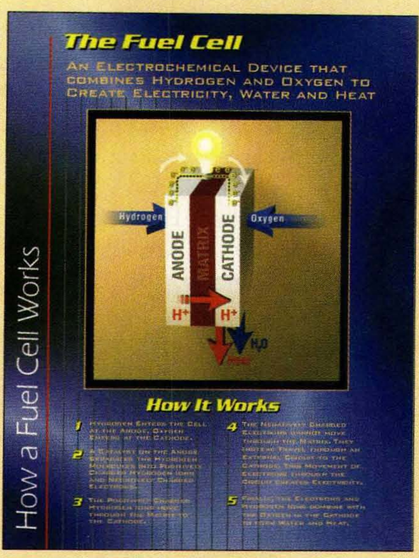
Fuel cells also hold potential for military applications, including self-sufficient undersea energy systems, mobile warfare, and power for fleet vehicles and weapons systems. HNEI is examining several types of fuel cells in its program — solid oxide fuel cells, proton exchange membrane fuel cells, enzyme fuel cells, biocarbon fuel cells, and methane hydrate benthic fuel cells.

"The Hawaii Fuel Cell Test Facility addresses fuel cell technology and fueling issues, including evaluation of a potential fuel source called C-4 methane hydrate," Dr. Richard Rocheleau, director of HNEI, said. "The Hawaii Fuel Cell Test Facility is the signature project of the fuel cell effort. We also have research activities in progress, but the fuel cell facility is the high visibility component of our effort. This facility is being designed to test individual fuel cell systems. It's not a demonstration project. It's a focus on the scientific performance aspects of fuel cells. The facility focuses on performance characteristics, fueling requirements, operating characteristics, durability issues, and so forth."

According to Rocheleau, fuel cell systems are potentially more efficient than internal combustion engines. The systems emit low emission, and produce essentially no noise, relative to other power generation systems. Fuel cells offer cleaner, more efficient use of fuel. Fuel cells are compatible with technology such as renewable hydrogen, which could advance wider acceptance of renewable technologies. It could also provide a means of taking renewable energy and applying it to the transportation sector. That particular application, Rocheleau noted, is still costly, in terms of where it needs to be.

"We are somewhat in our infancy in getting this going, but essentially the systems that we are putting in are designed to test what might be called full-size, single-cell fuel cells," Rocheleau said. "We are looking at fuel cells that are going to be relatively large, in the order of several hundred square centimeters. A single fuel cell — one membrane with the component parts on either side — is a lot like a low-voltage battery. It produces a current, which is proportional to the area. It's relatively low voltage, because it's dominated by electrochemical characteristics of the fuels and the system."

Rocheleau explained that a fuel cell stack — which is what HNEI refers to as its fuel cell system — is a number of fuel cells stacked up, to achieve high voltage and current. HNEI will test commercial-size fuel cells. The fuel cells will take up a large area, but only be single cell. It allows HNEI to begin to address not only the scientific issues, but also the engineering issues associated with the technology, such as water management, heat trans-



This is a diagram of how a fuel cell works. Each cell is stacked in a series.

Courtesy of UTC Fuel Cells.

fer, the fuel feeding system, and so forth. HNEI would be unable to address such issues in a university laboratory.

HNEI is addressing challenges from both a scientific and engineering perspective. With the technology that Rocheleau and his team are looking at, the voltage is fixed by the materials being used, typically less than one volt. The current is a function of the area, so there are a number of types of technologies people are looking at for personal projects, or portable systems — whether it's for a cellular phone or a computer. There are two issues that made this technology a reality, according to Rocheleau. One is getting fuel cells cheaper. The other is addressing the fuel issue, particularly in Hawaii where there isn't natural gas.

"Our strategy is to work with industrial partnerships and government partnerships, and to identify critical, technical hurdles, and conduct work necessary to solve the hurdles," Rocheleau said. "We're not trying to invent fuel cells from the ground up. We're trying to work with people we know are far along already. What we hope people will come away with is a realistic perspective of what fuel cells can and can't do. I think there are opportunities for the use of this technology in a lot of areas, but I think there's also a lot of hype in terms of what fuel cells will do in the short term."

One of HNEI's objectives is to get the technology into the marketplace. However, Rocheleau also wants to provide people with a realistic perspective of where the technology is today. HNEI expects in future phases, possibly next calendar year, to move into stacks of fuel cell systems. The initial work is on 10 single-cell fuel cells. HNEI also expects to move into solid oxide testing and development. Rocheleau noted that many people have contributed to the technology, including UTC Fuel Cells — one of the leaders in fuel cell technology. UTC provided fuel cells for NASA. The company has a commercial product on the market, which is a phosphoric acid fuel cell.

"There are many applications for this technology, including stationary power, transportation, powering of instrumentation, portable systems, and the military is looking at it to replace batteries," Rocheleau said. "Fuel cell technology can be applied to anything that uses an engine or battery. It's a multi-billion dollar market, potentially. It comes down to performance and cost. It has to beat the competition. From a safety point of view, hydrogen has a reputation and you have to handle it carefully, it's probably no more dangerous than other fuels handled in the United States on a routine basis. The inherent risk is no worse than using gasoline or natural gas."

Where does Rocheleau see fuel cell technology in the next five to 10 years? "I think we will see fuel cells getting out in the military," Rocheleau said. "In the commercial sector, we will see it in stationary power applications, as well as in areas where it is difficult to install power plants, areas with good fueling options, and areas without good conventional fueling options. In the transportation sector, we'll see demonstrations and vehicles, but it will take five to 10 years to get costs down to where the technology is effective in vehicles."

Rocheleau noted that people have talked about being competitive in a stationary market at about $1,000.00 to $1,500.00 a kilowatt, based on the peak capacity of a fuel cell. To put it in a car, and compete with today's engine, the cost has to be less than $100.00. Rocheleau sees long, steady growth with fuel cell technology, with acceptance not occurring overnight.

"We're trying to work with the people in Hawaii and the project is in the early stages at this point" John Petrik of the Office of Naval Research (ONR) said. "We're trying to work with them along the way if there's specific things that they might consider on how to test for fuel cells and if they are Navy-type applications such as shipboard applications — within a marine-type environment with salt and issues such as that. What the Navy is interested in specifically is if fuel cell technology can be used aboard ship for greater fuel efficiency. Also, for the possibility that the technology may provide for lower emissions."

One of the possible payoffs for the technology, Petrik noted, relates to when a ship is docked or what they call "the hotel load" situation — when a ship has to run electricity while in port. When a ship does that, then it's using gas turbines in a fairly inefficient mode. Also, emissions may be high, so if a ship can use a fuel cell in that particular application, then it achieves higher efficiency, as well as cleaner emission. From the standpoint of ONR, one of the issues it is dealing with is how to operate a fuel cell in a

You will find information about fuel cell technology at the following web addresses:

www.hnei.hawaii.edu
www.onr.navy.mil
www.howstuffworks.com/fuel-cell.htm

You will find information about how fuel cell technology can be applied to hobby projects at the following web addresses:

www.utoypia.com
www.fuelcell.gr/fuel-cell-science-project.pdf
www.fuelcell-info.com/public/285.cfm

marine environment. There are special issues such as a salt environment, the aspect of ship motion, and since it's a wartime capability, such things as how it may affect the signatures, since fuel cells have a lower temperature emission than a gas turbine.

So how can a hobbyist apply the technology to a project? "On the web, there are a lot of sites where a hobbyist can buy fuel cells," Petrik said. "For the hobbyist, you can hook up a solar cell into water, electrolyte the water, make the hydrogen, and you can feed that back into the fuel cell. Some companies — such as H-Power — sell small portable complete units that can be used as demonstration units. These portable units for example, can be demonstrated in a classroom."

One of those things that ONR does is to look at the science of fuel cells, according to Petrik. They are becoming commercially available as large units. Mid-size units are being used to power individual homes. ONR invests in research because there's much improvement in the technology that can be made. It's at the stage similar to where the Model T was at a point in time. The technology is actually old technology, because it was formulated in the mid-1800s.

One of the contributors to cost of the fuel cells, Petrik pointed out, is that platinum is required to catalyze the process, and platinum is costly. So researchers are developing electrodes that use much less platinum to achieve the same performance characteristics. Even the cost of membranes is high. More cost-effective manufacturing capabilities are being looked at. Currently, fuel cells are not made on a continuous line. There's much hand tooling and personnel involved.

"When you look at fuel cell technology, it's based on hydrogen," Petrik said. "So even though a lot of people say that hydrogen is safe, the biggest issue is that you simply don't have the infrastructure set up for safe handling of hydrogen. Some people argue that it's safer than gasoline. From a cost standpoint, I think it's even a bit expensive, but not outrageous that these things show up as portable power sources for homes. You'll see this technology showing up in electronics, because there's a lot of work developing these as battery replacements." **NV**

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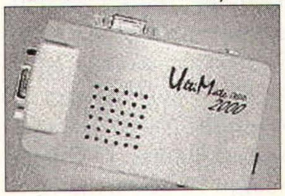

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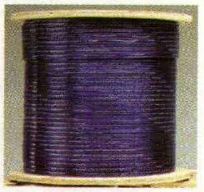

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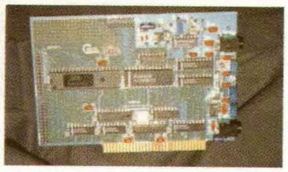

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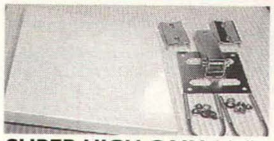

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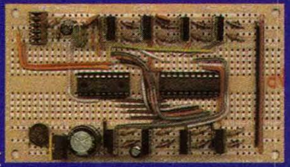

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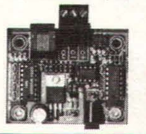

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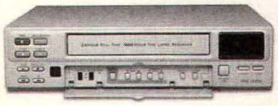

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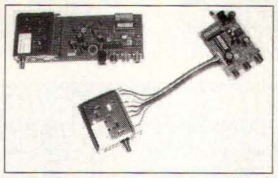

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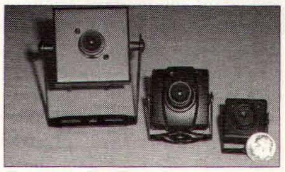

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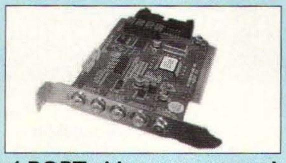

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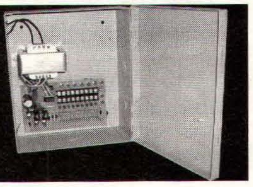

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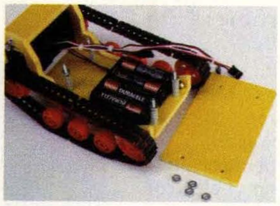

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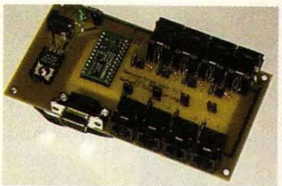

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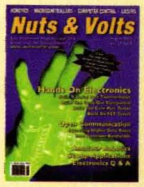

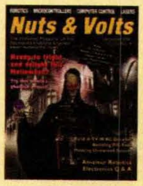

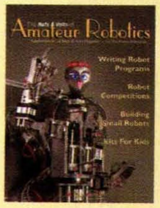

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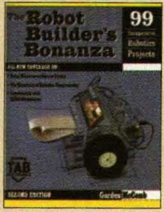

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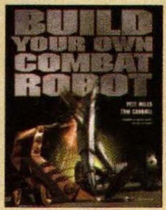

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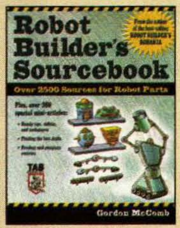

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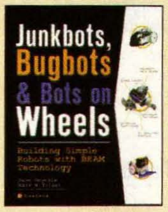

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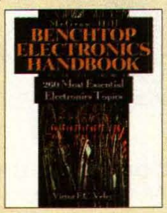

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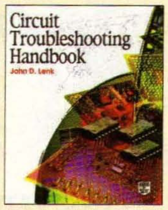

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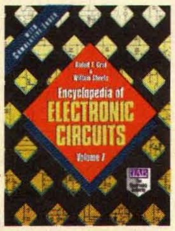

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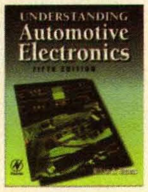

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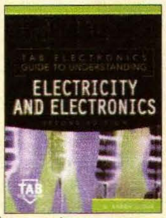

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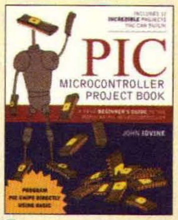

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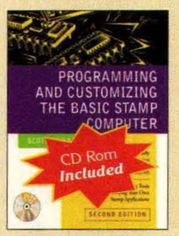

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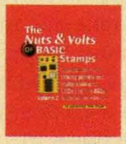

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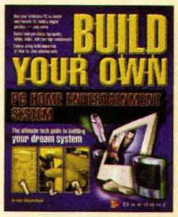

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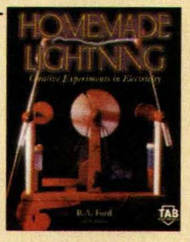

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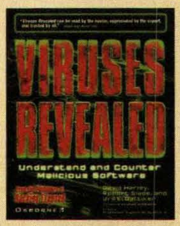

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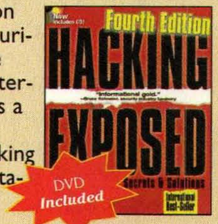

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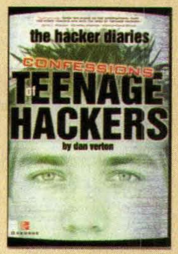

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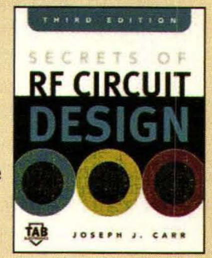

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Return to Interferometers

In last month's column, I discussed the various results obtained when using a Fizeau-type interferometer to inspect mirror surfaces. The interference fringes mentioned were first noticed by Sir Isaac Newton — back in the 17th century — although he wasn't sure at the time what the significance of the fringes was. They were called Newton's Rings after the great man, and are still referred to in some of today's scientific texts.

It wasn't until 1801, when Thomas Young showed the world the importance of these interference fringes that the true nature of light was widely accepted. If you read last month's column, you'll know that it was Young who hit the nail on the head, so to speak, and convinced the scientists of the day that light was a wave motion, and not the particle motion Newton had believed.

Also last month, I made mention of various interferometer types, and listed a few of the more familiar ones at the end of the column. One type that I had deliberately left out though, was the Michelson interferometer that was mentioned early in the column. I left that one out because the column was getting too long. Now you'll see why I left it out. There is a very interesting story surrounding the development of this interferometer, and I will share it with you now.

Background leading up to the experiment

First, a little background. In the mid-19th century, it was firmly established through Young and others, that light was a wave motion, just as sound is. It was believed that because of the wave nature of light, it required an elastic medium in which to travel. After all, sound needed air to travel, so it should be the same for light. The name given to this invisible, undetectable medium was ether. It was thought to permeate everything, even down to the molecular level. It had to surround even the tiniest things, because you could see small objects through a microscope. It was inconceivable to the scientists of the day that light could travel in a vacuum, so there had to be another medium — the ether. A vacuum may devoid a glass bell jar of air, but the jar is still full of ether — you can still see through it!

Various tests were performed to detect this ether, but all had failed. In 1875, the famous British scientist James Clark Maxwell, proposed a method whereby the ether could be detected, if it existed at all. An analogy of Maxwell's proposed method is this: It was well known, and easily demonstrated, that a rower on a flowing river will take a longer time to travel a fixed distance against the current, than when he rows with the current, if you assume a constant speed. At the same time, a rower traveling perpendicular to the flow will be able to do a return trip in equal crossing times.

Since the rower will travel faster with the current than against it, it might be supposed that the round trip time will be the same, but actually, rowing against the flow will be effective for a longer time, so therefore the total round trip time will be longer. If the number of trips were increased, then the total difference in travel time will be magnified by the number of trips, again assuming a constant speed.

Following this analogy — Maxwell proposed — if the ether was present, and the earth was traveling through it at close to 20 miles/second (the earth's speed through the ether is equal to D x PI / (365. 25 x 24 x 60 x 60), where D is the diameter of the earth's orbit around the sun. Doing the math, this works out to 18.5 miles/second, then there should be some 'ether wind' relative to the earth's motion, just as the water flow is relative to the rower's motion. The ether wind should have an effect on the speed of light, and should therefore, be easily detectable.

In 1881, Albert Michelson performed the experiment outlined by Maxwell. It was at the University of Berlin — at the laboratory of Hermann von Helmholtz — that the experiment was first set up by Michelson. To his great surprise, he could not see any difference in the velocity of light, regardless of the direction the light was traveling in. Some years before, the German scientist Ernst Mach (whose name is now synonymous with the speed of sound) proposed that the idea of an all-pervading ether should be dropped, but the known physics at the time would not allow such a preposterous notion.

The failure of the experiment was believed to be due to the set-up of the equipment, and the crude method of data gathering. However, it was believed that the experiment had a sound basis, and a better designed experiment should show positive results. Michelson himself thought so, and was eager to try again.

Michelson resigned his naval commission, and took a position as professor at the Case School of Applied Sciences (now the Case Institute) in Cleveland, OH. While teaching there, he met Edward Morley, who was teaching chemistry at Western Reserve University. The two men became good friends, and were to later work together on a revised version of Michelson's experiment.

The Michelson-Morley experiment

In 1887, Michelson and Morley set up an experiment in Morley's base-ment laboratory.

Figure 22-1 shows the Michelson-Morley interferometer set-up. A light source is placed at the input to the collimating lens pair as indicated. Each of the four mirrors M1, M2, M3, and M4, were actually composed of several separate mirrors, each adjustable for precise light-ray positioning on the next mirror. The mirrors were positioned very carefully, so that each of the light beams traversed the path a total of eight times, and were set up so that the total length of the light path in each arm of the interferometer was the same. The longer the path length, the greater indication will be given of timing change, analogous to multiple trips on the river. The assembly was mounted on a five-foot square slab of stone about a foot thick, and floated on a mercury pool. Thus, the arrangement was very stable, and allowed the whole assembly to be rotated slowly around a central pin.

The light source was directed onto a beam splitter BS1, which then sent two beams in orthogonal directions. The two beams were then reflected by the series of mirrors to increase the path length, before the final mirrors sent the two beams to meet at a screen SC1. Details of the mirror arrangement are not shown here for clarity.

The idea was that — under the strictly-controlled conditions in Morley's lab — an interference pattern should appear on the screen SC1 when the equipment is set up. As the assembly was rotated, the difference in the relative speed of the light beams crossing between the mirrors would cause a shift in the interference pattern because the speed of light would change, depending on whether it was in the same direction as the ether wind or perpendicular to it. The combining of the two beams on the screen SC1 would then give a clue to the absolute velocity of the earth with respect to the ether, which was assumed to be stationary, and everything else in the universe moved through it. The scientists of the day were very excited about this, because they could see no flaws in the reasoning of the experiment, and they thought that this would be a breakthrough into the fundamental laws of nature. Alas, it was not to be. When the arrangement was rotated, there was no change in the interference pattern. The experiment was repeated many times, but still failed to give any change in the interference pattern.

Witnesses to the experiment thought that perhaps there was a mistake in the alignment of the mirrors, or perhaps there was an error in the interpretation of the interference fringes. The experiments were repeated by other scientists, and again by Michelson and Morley, this time using an even more sensitive arrangement, but again, no ether wind was detected. Since the invention of the laser, extremely-sensitive experiments have been constructed to detect even a slight difference in the velocity of light, but so far, none has been detected. In fact, one of the inventors of the laser has tried this experiment himself.

Charles Hard Townes — then of Columbia University — used a MASER (an atomic clock) in an extremely sensitive set-up, in which any change in the speed of light could be detected, even if the speed of the earth was only 1/1000th of its actual speed. Again, there was no trace of an ether wind.

Scientists and physicists were so amazed by the negative results of these tests, that they began inventing all sorts of explanations to save the ether-wind theory. But the strangest of all explanations came from an Irish physicist, George Francis Fitzgerald. The reason, he said, that the experiment failed is because the ether wind puts a force on the equipment, making it contract a little in the direction of its motion. The amount of contraction, he said, would be just enough to offset the change in the speed of light. This notion — crazy as it seems — became known as the Fitzgerald contraction. Hendrick Lorentz — the Dutch physicist — had independently thought of the same explanation. The theory later was changed to the Lorentz-Fitzgerald (or Fitzgerald-Lorentz) contraction. Albert Einstein later became good friends with Lorentz, worked out the math, and incorporated this contraction in his general theory of relativity, published in 1905. Although the experiments of Michelson and Morley will go down in history as a failure, the scientific world looks upon the experiment as a resounding success, because it forever did away with the impossible task of detecting an invisible, light-bearing ether.

Light and optics are a fascinating subject, and we continue to develop more sophisticated instruments to measure every characteristic of electromagnetic radiation. With such a wide coverage as the electromagnetic spectrum provides, there is still plenty of room for experiment.

As always, if you have any questions about this column, or about optics and lasers in general, please contact me through email at **stanley.york@att.net**. **NV**

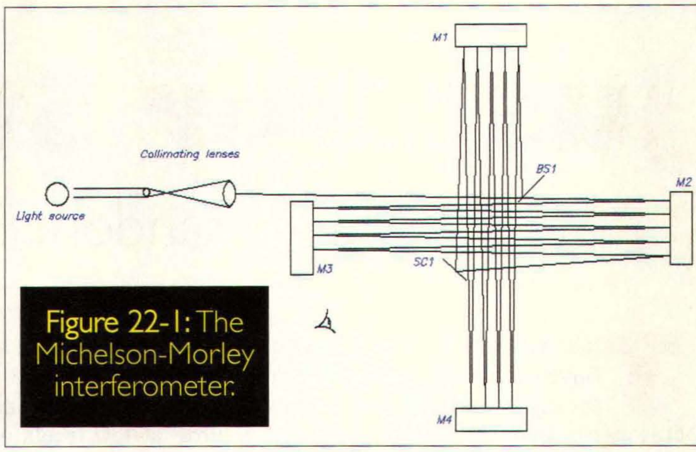

Figure 22-1: The Michelson-Morley interferometer.

Basics For Beginners

Just For Starters

Random Thoughts

This month, we are going to have a series of "random thoughts." These are some little items that can come in handy for working with electronics.

To put screws in hard-to-reach places, take a small piece of tape and push the screw through it from the sticky side. Then place the screw on the screwdriver and fold the edges of the tape up around the screwdriver tip. This will hold the screw while you start it.

A heavily-magnetized screwdriver will, of course, hold the screw for you. However, many of today's projects contain parts that are sensitive to magnetism. Working with magnetized tools around computers is asking for trouble. I regularly demagnetize my tools with a tape-head demagnetizer from RadioShack.

When wiring a volume control — if you follow the diagram in Figure 1 — the volume will increase as you turn the knob clockwise.

Now, there are several things you need to be aware of in this area. First, there are two different types of potentiometers (pots) that look the same on the outside, but are different on the inside. The human ear does not detect changes in volume at low levels as well as it does at higher levels. Therefore, an "audio taper" volume control will increase the audio very rapidly at first and then, as you continue to turn the knob, the increase in volume will be less for the same knob travel. Anytime you are replacing a pot that is used for a volume control, be sure that it is an "audio taper" pot.

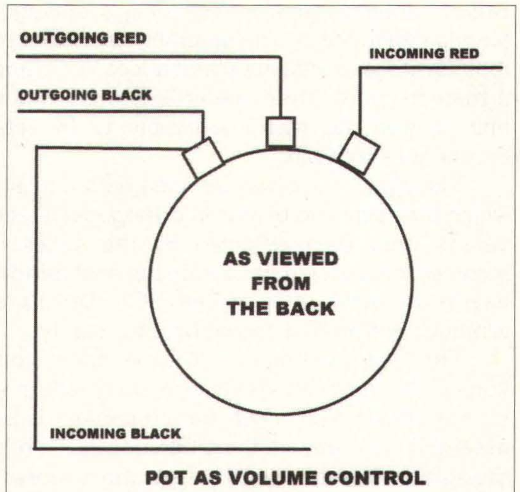

Figure 1

The other type of pot is a "linear taper" and — as its name says — will have a constant rate of change in resistance for a given movement of the knob. These are used for voltage control and are quite often wired as shown in Figure 2. This makes the pot serve as a continuously variable resistor.

When you look at an electrical outlet or plug, you will notice that one of the flat blades is smaller than the other. This is the one that ties to the hot side of the line and the larger one is neutral. You will also notice that one of the internal connections — where you attach the wire — will be silver and the other gold. Normally, you will have three wires: black, white, and green.

The green is *always* your ground lug, the round pin. Black is your hot side and goes to the gold terminal. White is the neutral and goes to the silver terminal.

The easy way to remember this is to think of oil — black gold — because black goes to gold.

Some of us remember when Touchtone™ phones first came out. They were polarity-sensitive and, if you reversed the tip and ring when wiring the phone line, the tone pad would not function. The tone pad is powered, of course, by the holding voltage on the phone line (approximately 28 volts).

However, before too long the new phones coming out were no longer polarity-sensitive. This was accomplished with a simple bridge-diode arrangement as shown in Figure 3.

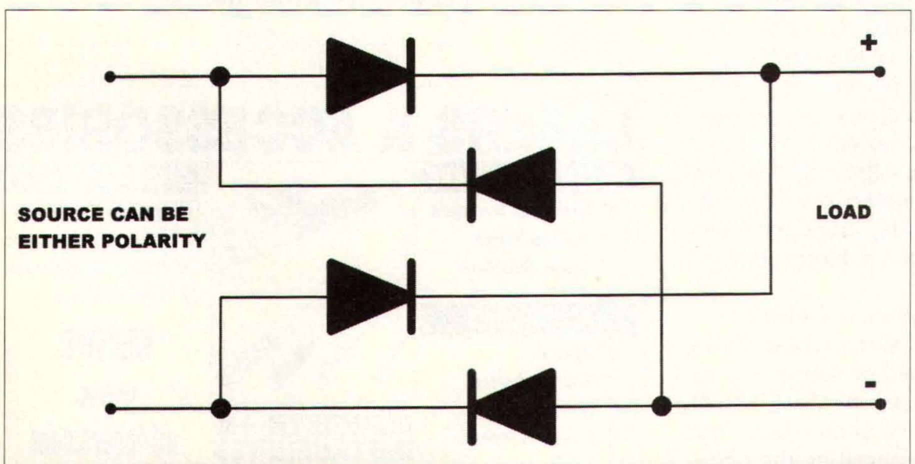

Figure 3

By using this bridge arrangement, you can apply a DC voltage in either polarity and the unit — whatever it is — will work. You will have some voltage drop (approximately 1.5V) through the circuit since the forward diodes will present some resistance. But if you are building something, and you want it to function on either polarity, you can use this on the input.

If you are using a regulated supply, you simply allow for the voltage drop. Your unregulated supplies are going to wander around with the load anyway. Therefore, if you are using an unregulated supply (like most wall warts) and it is labeled 12 volts, it will actually supply considerably more voltage until you load it down. Most circuits will not notice the slight voltage drop caused by the diodes. And, it will make your project much more goof-proof when applying the voltage. **NV**

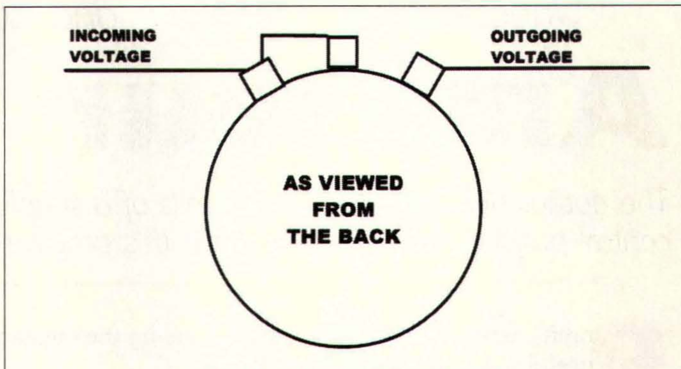

Figure 2

Understanding, Designing, and Constructing Robots & Robotic Systems

Amateur Robotics

The author provides code and details of a simple printf() function for use in robotics and embedded control projects. Small and versatile, this program will be a powerful addition to your next design.

Printf() ranks as one of the most useful of C's basic functions. It provides a simple method of displaying formatted data, such as strings, integers, and floating-point numbers. It is also a powerful debugging tool, since adding a few judicious printf calls to your code can quickly zero-in on trouble spots.

Traditionally, the first C program you write uses a call to printf to display the string "Hello, world!" If you compile that program on a PC, you can easily generate an executable that is 100K or larger. If you build that same program for use in a robot or in an embedded control environment, you will often end up with an executable more than 50K in size.

In the Oct. 2002 issue, I showed how to set up the GNU C compiler for the Motorola 68hc12 microcontroller (MCU). My target 'hc12 system is a Technological Arts Adapt912b32 board, which carries 32K of flash. When I compiled the "Hello, world!" program for the 68hc12, the resulting executable exceeded my available flash memory.

The reason for this code bloat lies in printf's kitchen-sink approach to displaying data. Printf can handle any type of data, including data types you don't normally need in robot code. For example, most small robots don't use floats or doubles, since floating-point operations take a lot of time to perform and the attendant math packages are relatively large. But if your code invokes printf even once, the linker brings in everything printf needs to display floats, even if your code never displays a float.

The problem becomes, then, how to get the benefits of printf without using up all of your available memory to display a string. The answer lies in a bit of custom code that duplicates the essential features of printf without adding the baggage of unused parts.

Printing strings

At its most basic, printf prints strings. In C, a string is a sequence of bytes, terminated with a byte of 0. For example, the string "123" appears as the following sequence of bytes, shown here in hexadecimal:

$31 $32 $33 $00

Printing such a string in C is simple. Write the starting address of the string to a pointer variable. Repeatedly read the character pointed to by that variable and, if the character is non-zero, display that character and increment the pointer. If the character fetched from that pointer is zero, the print operation is done. Listing 1 shows what that code looks like in C; I'll call the function prints, since all it does is print a string.

Actually, I need to beef up this function just a bit. C uses a number of escape characters to embed extra formatting within a string. These are typically a two-character sequence — a backslash followed by a second character that defines the requested action. Escape sequences exist for carriage-returns, form-feeds, beeps, and other useful actions. For example, the sequence "\n" represents a new-line (line-feed) character.

In Listing 2, I've added code that tests for the presence of a new-line character; if the new-line is printed, this function now follows it immediately with a carriage-return character.

```
void prints(char *str)
{
   while (*str)
   {
      putch(*str);
      str++;
   }
}
```

Listing 1: A simple string-printing function.

```
void prints(char *str)
{
   while (*str)
   {
      putch(*str);
      if (*str == '\n')  putch('\r');
      str++;
   }
}
```

Listing 2: An improved prints function.

This means I can write a string containing a "\n" sequence, but when the string is displayed, my prints function will translate this new-line into a new-line, carriage-return sequence automatically.

The putch() function

As you've no doubt noticed, the above two functions use a second function — putch — to display a character. In the PC world, this causes a character to appear on your monitor. In the embedded world, this function does not normally exist. You — as the programmer — are responsible for creating this low-level function.

The actual code will vary, depending on the output device used. You might need to display characters on an LCD screen, send them to an RS-232 serial port, or write them to a parallel port. Since you (presumably) know all the details of how your output device works, you must write the function for displaying data to that device.

The 'b32 version of the 68hc12 has a single SCI port, used to exchange data over a serial line such as an RS-232 port. Writing the equivalent of a putch function that sends characters out the SCI port can be as simple as polling the SCI transmit register until it is empty, then writing a character to the SCI data register; refer to Listing 3.

Note that this isn't a very good putch function. Because it locks in a loop polling the SCI port for a certain

```
void putch(int c)
{
    while (SC0SR1 & SCI_TDRE) == 0) ;
    SC0DRL = c & 0xff;
}
```

Listing 3: A simple putch function.

condition, it prevents the CPU from doing anything else until the character is sent. For simple robots, this won't normally be a problem. As your projects get more advanced, you will probably move to more sophisticated I/O functions that use interrupts and callbacks to free up the processor as much as possible. For now, however, polling functions like this will get the job done.

Device selectors

But the above function has what I consider an even greater disadvantage; it only sends characters to SCI port 0. If I want to send a character to a second SCI port — such as exists on an 'a4 variant of the 68hc12, or to an LCD screen — I'm stuck. I would need to write different versions of putch. But because prints calls putch directly, I would also need to rewrite prints for each output device. Then, if my high-level code wants to talk to different output devices, I have to write extra code to call each different prints as needed. This kind of special-case code quickly becomes unwieldy and hard to maintain.

A better approach is to write putch so my code passes not only the character to print, but some type of device selector. The putch function uses this selector value to decide which low-level display routine to call. Now I only need to write a version of prints that also accepts this device selector value and passes it on to putch.

Actually, to avoid confusion with the putch function — whose characteristics are carefully defined by the C standard — I'll call my character output function printc. Listing 4 shows a version of prints that accepts an argument called port, which determines the function to use for sending a character. Note that the prints function itself does not care what value port holds; it simply passes the port value on to the printc function.

We're nearly done. All that remains is the printc function itself. Listing 5 shows a version of printc that supports one I/O device, SCI port 0 on the 68hc12b32. If your code calls this function with a port identifier other than SCI_PORT0, no character is output.

You'll notice that prints uses a pointer to an array of unsigned chars, while printc expects a character passed as an unsigned short int. The printc function supports exchanging nine-bit data with a physical device, perhaps over an RS-485 network. Some multi-drop protocols send the first character of a packet with the ninth-bit set to indicate an address byte; other characters within that packet are sent using only eight bits. I wrote printc this way to leave open the possibility of supporting such a multi-drop network. The above prints and printc functions allow my code to display a simple string of characters. For example, the following function call will output a string, complete with two CRLFs at the end, to SCI 0 on my Technological Arts board:

```
prints(SCI_PORT0, "This is a
simple string!\n\n");
```

Low-level I/O

Of course, I also need routines that do the low-level work of sending characters out the SCI port. Without going into a lot of detail, Listing 6 shows functions for opening SCI 0 for output and sending a character out that port.

SCI_Open lets my code set the baud rate, parity, and other operating parameters for the SCI port; note that it

```
/*
 *  prints    print a string to an I/O port
 *
 *  This routine prints the string passed
 *  as argument str to the I/O port
 *  identified by argument port.
 *
 *  \r characters are printed without
 *  modification. \n characters are
 *  always followed by a \r.
 *
 */

void prints(short int port, unsigned
char *str)
{
    while (*str)
    {
        printc(port, (unsigned short
        int)(*str));
        if (*str == '\n') printc(port, '\r');
        str++;
    }
}
```

Listing 4: Supporting multiple output devices in prints.

```
/*
 *  printc    print a character to an I/O
 *  port
 *
 *  This routine prints the character
 *  passed as argument c to the I/O
 *  port identified by argument port.
 */

void printc(short int port, unsigned
short int c)
{
    switch (port)
    {
        case SCI_PORT0:
        SCI_SendChar(0, c);
        break;

        default:
        break;
    }
}
```

Listing 5: A printc that supports SCI 0.

currently only supports SCI 0. SCI_SendChar sends the specified character to the selected port; again, it only supports SCI 0. The SCI_XmitPoll function polls the selected port and returns a value indicating whether the port is ready to send a character.

Printing data values

But robot code involves more than simple text strings. Often, your code needs to report sensor values, motor settings, location information, and other details. This requires the ability to convert a variable's value into a formatted string of characters.

We already know that the traditional function for this job — printf — is overkill for most robotic applications. What we need is a stripped-down printf. The function discussed here — which I call printv — accepts a port identifier, a format string, and a single int value. It formats the value as directed by the format string, then writes the resulting character string to the selected port.

To keep the size of the function down, I've removed some of printf's features. My printv does not accept a variable-length argument list; it is limited to a single int variable. It does not handle floats or doubles. It does, however, support width specifiers, and can display a value in unsigned decimal, signed decimal, or unsigned hexadecimal; hex values can be shown as uppercase or lowercase. It also provides leading zeros or leading spaces. Best of all, it weighs in at just about 5K of code, well below the 30K+ of the full printf. Refer to Listing 7 for details. The real work of formatting a string is carried out by the sprintv function. I separated the formatting operation from the printing operation so my code could format a string without having to print it, should that be necessary. The entire sprintv function is too large to include here, so I'll just hit some of the high points. A typical invocation of sprintv might look like this:

```
sprintv(buff, "d", foo);
```

This invocation takes the value in foo, formats it as a signed decimal number, and copies the resulting string to the buffer at address buff. If foo holds a negative number, it is formatted with leading negative sign. The resulting string uses the minimum amount of characters to hold the formatted value. Here is another example of sprintv's power:

```
short int  SCI_Open(short int  chnl,
                    unsigned short int  baud,
                    short int  nbits,
                    short int  parity)
{
    short int              result;
    unsigned short int     br;
    short int              mode;

    switch  (chnl)        // based on
                          channel number
    {
        case  SCI_PORT0:    // SCI 0
        br = (((MCLK / 16) / baud) &
            0x1fff);
        SC0BDH = br >> 8;
        SC0BDL = br & 0xff;    // must
            write low byte last!

        mode = 0;         // clear out
            the mode value
        if (nbits == SCI_8BITS)   ;
        else if (nbits == SCI_9BITS)
        mode |= SCI_M;
        else
        {
            result = SCI_BAD_PARAMETER;
            goto  openerror;
        }

        switch  (parity)      // based on
                              type of parity
        {
            case  SCI_NOPARITY:
            break;

            case  SCI_ODDPARITY:
            mode = mode | SCI_PE |
             SCI_PT;
            break;

            case  SCI_EVENPARITY:
            mode = mode | SCI_PE;
            break;

            default:
            result = SCI_BAD_PARAMETER;
            goto openerror;     // bad
                                parity value
        }
        SC0CR1 = mode;
        SC0CR2 = SCI_TE | SCI_RE;
        result = SCI_OK;
        break;

        case  SCI_PORT1:
        result = SCI_NO_SUCH_PORT;
        break;

        default:
        result = SCI_NO_SUCH_PORT;
        break;
    }
openerror:
    return  result;
}


short int  SCI_SendChar(short int  chnl,
                        unsigned short int  c)
{
    short int             result;

    switch  (chnl)
    {
        case  SCI_PORT0:
        while (SCI_XmitPoll(chnl) ==
        SCI_XMIT_NOT_RDY)  ;
        if (SC0CR1 & SCI_M)
            // if sending 9-bit mode...
        {
            if (c & 0x0100)
            // if ninth bit is set...
            {
                SC0DRH = SCI_T8;
            // set ninth bit in output
            }
            else
            {
                SC0DRH = 0;
            // clear ninth bit
            }
        }
        SC0DRL = c & 0xff;
            // send low eight bits
        result = SCI_OK;
        break;

        default:
        result = SCI_NO_SUCH_PORT;
        break;
    }
    return  result;
}


short int  SCI_XmitPoll(short int  chnl)
{
    short int             result;

    result = SCI_XMIT_NOT_RDY;
            // assume not ready
    switch  (chnl)
    {
        case  SCI_PORT0:
        if ((SC0SR1 & SCI_TDRE) != 0)
            // if TDR is empty
        {
            result = SCI_OK;
        }
        break;

        default:
        result = SCI_NO_SUCH_PORT;
    }
    return  result;
}
```

Listing 6: Low-level serial I/O functions.

```
/*
 *  printv    print a value as a formatted
 *  string
 *
 *  This routine uses a call to sprintv()
 *  to format a value into a string, then
 *  prints that string to the port
 *  identified by argument port.
 *
 *  The format string should be passed
 *  as argument fmt. The value to be for-
 *  matted is passed as argument v.
 */

void printv(short int  port,
        unsigned char  *fmt,
        int  v)
{
    unsigned char        buff[256];

    sprintv(buff, fmt, v);
    prints(port, buff);
}
```

Listing 7: A formatted print function.

```
void ShowMemory(unsigned char
*addr, int  num)
{
    unsigned short int              n;
    unsigned char                   *p;

    n = ((unsigned short int)addr &
        0xfff0);
    p = (unsigned char *)n;
    num = num + (addr - p);
    prints(SCI_PORT0, "\nAddr  +0 +1
        +2 +3 +4 +5 +6");
    prints(SCI_PORT0, " +7 +8 +9 +a +b
        +c +d +e +f");
    for (n=0; n<num; n++)
    {
        if (n % 16 == 0)
        {
            prints(SCI_PORT0, "\n");
            printv(SCI_PORT0, "4x",
            (unsigned int)(addr+n));
            prints(SCI_PORT0, "  ");
        }
        printv(SCI_PORT0, "02x", *p++);
        prints(SCI_PORT0, " ");
    }
    prints(SCI_PORT0, "\n");
}
```

Listing 8: A memory dump function using printv.

```
sprintv(buff, "-10u", bar);
```

This causes sprintv to format the contents of bar into a string 10 characters long, with the value left-aligned as an unsigned decimal number; the string will be padded to the right with spaces. Finally, Listing 8 shows a larger example of using the entire package of print functions. This is a memory dump function that displays an area of memory as a table of hexadecimal bytes, complete with column headings.

The code for converting a number into a string is straightforward and, frankly, a bit dull, but some of the techniques are worth studying, as you can use them later in other applications. I'll hit a couple of high points by discussing selected sections of the sprintv function. Review the following listings for details. I've added line numbers for reference only; obviously, they are not part of the C source file.

The code in Listing 9 parses the format string, setting flags and variables to record formatting elements such as justification, field width, radix, and, for hexadecimal only, use of uppercase or lowercase letters.

The code in lines 27 through 31 parses the width parameter, which specifies the total number of characters to assign to the converted string. The code shown here assumes that the resulting value will fit properly within an eight-bit variable. If you want to add safeguards to catch instances in which the format string calls out an excessively large width field, feel free to edit the code. The large switch statement starting at line 37 processes the single-letter radix declarator. Legal values appear in the case statements, with a default of 'u,' signifying unsigned decimal.

Listing 10 shows how sprintv builds up the smallest possible string for the value passed to it. This string is built up in reverse order (one's digit first) and saved in a local buffer on the stack. Note how this code automatically adjusts for radix and, if hexadecimal, handles the case of the letters.

All that remains is to copy characters into the buffer whose address was passed as an argument in the call to sprintv. If necessary, sprintv first adds any leading spaces or zeroes. Next, it copies the string just built by the code above, starting with the most-significant digit. Then, it adds any needed trailing spaces. Finally, it adds the terminating null byte and the string is ready to display on your LCD screen or send to your serial port.

```
1. /*
2. * Test for left-justification (leading '-' in
   format string).
3. */
4.
5.         if (*fmt == '-')
6.         {
7.                 fmt++;
8.                 ljust = 1;
9.         }

10. /*
11. * Check for zero-filled format (leading
    0 in width argument).
12. */

13.        if (*fmt == '0')
14.        {
15.                fmt++;
16.                zfill = 1;
17.        }

18. /*
19. * Process the width field. Legal
    characters are limited to '0'
20. * through '9'. Compute the width
    and save it in variable width.
21. * If variable width is signed,
    maximum width is 127; if it is
22. * unsigned, maximum width is 255.
23. *
24. * Width field is optional, defaulting to
    a width of 0.
25. */
26.
27.        while ((*fmt >= '0') && (*fmt <=
    '9'))
28.        {
29.                width = width * 10 +
    (*fmt - '0');
30.                fmt++;
31.        }

32. /*
33. * Next character in the format string
    MUST be a format specifier.
34. * If not, use the default format of 'u'
    (unsigned decimal).
35. */
36.
37.        switch (*fmt)
38.        {
39.            case 'd':
40.            radix = 10;
41.            tsigned = 1;
42.            lower = 0;
43.            break;

44.            case 'x':
45.            radix = 16;
46.            tsigned = 0;
47.            lower = 1;
48.            break;

49.            case 'X':
50.            radix = 16;
51.            tsigned = 0;
52.            lower = 0;
53.            break;

54.            case 'u':
55. default:
56.            radix = 10;
57.            tsigned = 0;
58.            lower = 0;
59.            break;
60.        }
```

Listing 9: Sprintv's parsing algorithm.

```
/*
 * Successively divide the value by the radix until the
 * result is 0. Convert each integer quotient into an
 * an ASCII character in the proper radix. If the
 * radix is hex, adjust the ASCII character based
 * on the 'x' or 'X' format specifier.

        while (v != 0)
    {
        *p = ((unsigned int)v % radix) + '0';
        if (radix == 16)
        {
                if (*p > '9')
                {
                        *p = *p + 7;
                        if (lower)
                        *p = *p + 32;
                }
        }
        p++;
        v = (unsigned int)v / radix;
    }
```

Listing 10: Converting a value to a string.

In conclusion

I've presented a set of functions that provide a stripped-down version of C's printf function. Suitable for use in robotics code, these functions let you write strings and formatted values to a selected I/O device. You can easily expand these functions to support other I/O devices by editing the printc function to handle other port identifiers. I will make the full print package described here available on my website. Running on a small platform, such as a 68hc12b32 in single-chip mode, does not mean you have to give up all of the capabilities of printf. Use these functions as the core of your own formatted print library; I think you'll enjoy the power they bring to your data displays. **NV** by Jon Williams

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

Stamp Applications

Mo' MIDI

Last month, we saw that it's fairly easy to send MIDI commands and play a stored song. What we did was easy, but not particularly interactive. This time, we'll use the BASIC Stamp as a sensor interface and send note-on and note-off commands based on the sensors.

When it comes right down to it, I'm a simple, fun-loving, goofy guy. I like movies, good coffee, pretty ladies (who doesn't?), and fun BASIC Stamp projects. I seem to get the most enjoyment out of the simplest of my projects. This month fits into that category: easy projects with simple hardware and code and I have had more fun playing with them than most projects I've created with BASIC Stamps in the last eight years.

Now, I know what you're thinking: "Why use the Stamp to send note-on and note-off commands when I have a perfectly good keyboard sitting right in front of me?" Well, you might want to do something more fun. Remember the on-the-floor keyboard that Tom Hanks and Robert Logia played in the movie *Big*? You could do that. Or create a neat, interactive sculpture as a museum piece. Kids, especially, like those kinds of things. And then, this 40-year-old kid likes them too!

A Custom Keyboard

A common topic on the BASIC Stamps [Yahoo! Groups] list is dealing with multiple simultaneous inputs and their change of states. Without fail, my good buddy Tracy Allen comes to the rescue with great information on finite state machines (**www.emesystems.com/BS2fsm.htm**) and how to take advantage of this programming strategy with BASIC Stamps.

We're going to put those techniques to use here and create a custom keyboard. For testing, we can use push buttons as in Figure 1 — use one circuit for each key. In our program, we'll keep things simple by using eight keys so that we can read them all at once by grabbing the status of InL (pins 0 through 7), which our program aliases as Keys.

Let's look at the scanning subroutine, then discuss how it works.

```
Get_Keys:
  scan = Keys
  changes = scan ^ last
  last = scan
  RETURN
```

This is actually quite simple, but what trips up many beginning BASIC Stamp programmers is the use of the Exclusive OR operator (^). The rule for XOR is "If one bit OR the other is set, but NOT both, the output will be True." Here's what it looks like as a truth table:

A	B	XOR
0	0	0
1	0	1
0	1	1
1	1	0

Another way to remember the behavior of XOR is that if the bits are different, the output will be True (1); if they're the same, the output will be False (0).

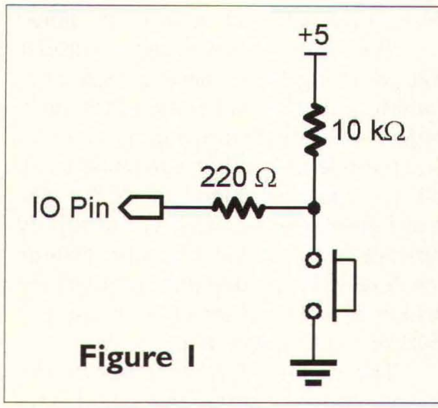

Figure 1

We can take advantage of this behavior by comparing the last key scan with the current scan. Any changes between them will appear as 1 in the changes variable. Let's say, for example, we start the program then press the keys connected to pins 7 and 5. The next time through the Get_Keys subroutine, we would see these values after the line that evaluates changes:

scan	%01011111
last	%11111111
changes	%10100000

Of course, after the changes have been evaluated, we store the current scan in the variable called last so that it's updated for the next time we call Get_Keys.

Now that we can tell what key (or keys) has changed — if any — sending MIDI commands is as easy as looping through the changes and acting accordingly.

```
Play_Notes:
  IF changes THEN
    FOR idx = 7 TO 0
        IF (changes.LowBit(idx))
THEN
      cmd = NoteOn - ($10 *
scan.LowBit(idx))
```

```
        note = MiddleC + (7 - idx)
        SEROUT MidiOut, MidiBaud, [cmd, note, velocity]
      ENDIF
    NEXT
  ENDIF
  RETURN
```

The first thing we'll check for is changes. We just saw that bits will only be set in changes if a key was pressed or released between scans. If there have been no changes, all bits will be zero and we can skip right past the rest of the subroutine code.

But let's say a key was pressed or released. We'll use a **FOR-NEXT** loop to scan the bits in changes to see what happened. When we find a 1 bit in changes, the command is calculated based on the corresponding bit value in scan. We can do this mathematically with just one line of code.

```
cmd = NoteOn - ($10 * scan.LowBit(idx))
```

The variable idx holds the bit (key position) we're evaluating. If the value of that bit in scan is zero, the key was pressed and the line above evaluates as:

cmd = $90 - ($10 * 0) = $90

If the key had been released, we'd get:

cmd = $90 - ($10 * 1) = $80

The note value is also calculated. Our keyboard works like a piano keyboard, with notes getting higher as we move left to right. The base note — Middle C — is assigned to bit 7, so our eight-bit keyboard will play these notes:

C-C#-D-Eb-E-F-F#-G

If we wanted to eliminate the sharps and flats, we could insert a **LOOKUP** table to assign the note value:

```
LOOKUP (idx - 7), [60, 62, 64, 65, 67, 69, 71, 72], note
```

The reason we subtract seven from idx is to align the table values with the keyboard; bit 7 corresponding to the first note value in the table.

Finally, we can add some life to our keyboard by allowing a volume (velocity) change for the notes we play. One way of doing this is to read the position of a potentiometer with an analog-to-digital converter. Figure 2 shows a simple set-up with ADC0831 — a part we've used many times in the past. Reading the position of the potentiometer is a no-brainer:

```
Get_Velocity:
  LOW A2Dcs
  SHIFTIN A2Ddata, A2Dclock, MSBPost, [velocity\9]
  HIGH A2Dcs
  velocity = velocity / 2
  RETURN
```

Since the ADC0831 returns a value of 0 to 255, we can scale it to a legal MIDI value (0 to 127) by dividing by two.

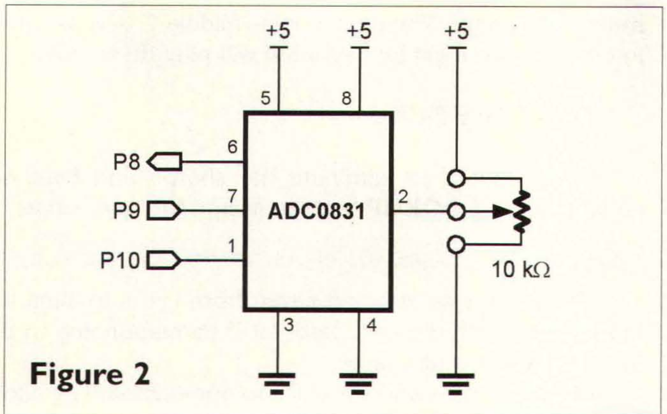

Figure 2

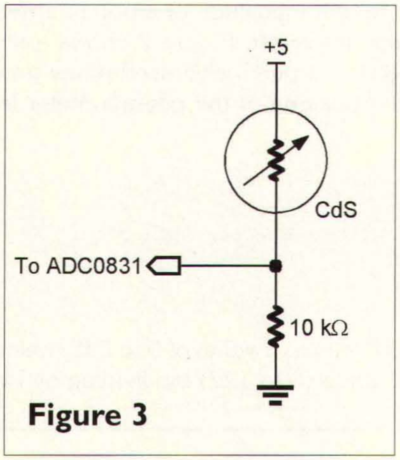

Figure 3

Easy. With everything in place, **SEROUT** sends the MIDI command to our instrument.

You may wonder why we don't just use **RCTIME** to read the potentiometer. The reason is that **RCTIME** is a time-based function, and can get quite long at large pot values. By using the ADC0831, the time to read the position of the pot is the same, regardless of its position. This strategy also lets us use other control [voltage] sources for the velocity level.

The advantage of keeping everything modular is that we can make sectional changes without upsetting the overall program design. It keeps the main loop organized and, with appropriate subroutine names, self-documenting of its behavior. Take a look:

```
Main:
  DO
      GOSUB Get_Keys
      GOSUB Get_Velocity
      GOSUB Play_Notes
  LOOP
  END
```

Very clean, isn't it? Technically, the END command is not needed in this program, but it's my programming habit to put it in between the main program loop and subroutines section. That way, if I add an **EXIT** command to this loop, I won't run into any unusual program behavior by having the code crash into the first subroutine on a loop exit.

Music By Light

We just saw how we could use the ADC0831 to set our volume by reading a pot. Let's create a new type of instrument by letting the light falling on a CdS photocell control our note. Replace the pot with the circuit shown in Figure 3 for light control.

What we're going to do with this program is use the light to control note value. While simple in concept, there is a bit of trickiness here, because we don't know how much light is going to be falling on the photocell when we start. What we need to do then, is scale the program on start-up to the ambient light.

When the program starts, we'll read the ambient light with our A2D subroutine:

```
Get_Note:
  LOW A2Dcs
  SHIFTIN A2Ddata, A2Dclock, MSBPost, [note\9]
  HIGH A2Dcs
  note = note */ scale MIN ScaleMin
  RETURN
```

The code should look familiar, we just used most of it to read our volume pot. The difference now is that we're using it to read our note. After reading the raw note value, we want to scale it for the ambient light and for our instrument. Here's where things get a little tricky.

We're actually going to call this routine from our initialization section after setting the value of scale to $0100 — or 1.00 for use with the */ (star-slash) operator. What we get, then, on this first read is the raw value of the ambient light. Let's go ahead and look at the initialization section.

```
Setup:
  HIGH A2Dcs
  scale = $0100
  GOSUB Get_Note
  scale = ScaleMax * $0100 / note
  GOSUB Get_Note
  last = note
  velocity = 96
```

What I want to focus on is this line:

```
  scale = ScaleMax * $0100 / note
```

Like many, I monitored the post-holiday sales and found a MIDI keyboard at RadioShack for less than $100.00. It's not a full-sized keyboard, though, and the highest note value it can play is 96. That's the value that ScaleMax is set to.

By shifting the ScaleMax value into the upper byte of scale, then dividing by the ambient light reading, we end up with a [fractional] value in scale that sets the ambient light level to the highest note on the keyboard. Let's step through the process.

If the raw value of note is 153, we get:

scale = 96 * 256 / 153 = 24576 / 153 = 160

Remember that we're using integer math in the BASIC Stamp, so we may get a slight rounding error. Also keep in mind that the value of scale is being used with */, so it actually represents units of 1/256. In our example, the equivalent fractional value is 160 / 256 = 0.625.

With the scale value set, we read the sensor again (which should give us the same raw value), but this time the scaling returns a note value of 95 — pretty close to our scale maximum.

153 */ 160 à 153 * 0.625 = 95

I'm not worried about the scale value not reaching the end of the keyboard because I actually want the keyboard not to play when the ambient light is falling on it. Here's the rest of our simple light-controlled MIDI instrument program:

```
Main:
  GOSUB Get_Note
  note = (note */ NMix) + (last */ LMix)
  IF (note = last) THEN Main
  IF (note > HighNote) THEN Last_Off

New_On:
  SEROUT MidiOut, MidiBaud, [NoteOn, note, velocity]
  PAUSE 5

Last_Off:
  SEROUT MidiOut, MidiBaud, [NoteOff, last, 0]
  last = note
  GOTO Main
  END
```

For a moment, let's skip past the line that follows the call to Get_Note and see how the rest of the program works. The first thing we're going to do is look at the current note and see if it's different from the last. If not, we'll go back and look again, waiting until we get a note change.

Once the note changes, we'll make sure it's in range. If not, we'll silence the instrument by jumping to Last_Off which will kill the last note we played. If the new note is in range, we'll play it and then wait just a bit before silencing the last one. This will mix the notes slightly and make the transition between them a little smoother (depending, of course, on the voice we have selected on the MIDI instrument).

Okay, let's go back and look at that line I skipped.

```
  note = (note */ NMix) + (last */ LMix)
```

What this line does is apply a very simple digital filter to our input so that the note value doesn't jitter around so much — which can be incredibly annoying when this program is actually connected to a MIDI keyboard. What it does is slows the changes between notes.

In the constants definition of the program, you'll find these lines:

```
MixPercent      CON     35
NMix            CON     $100 * MixPercent / 100
LMix            CON     $100 - NMix
```

This should look somewhat familiar, since we just discussed a technique for finding the appropriate value for scale when using the */ operator. What this code does is sets the value of NMix (new mix) to 35% and LMix (last mix) to 65% (100% - 35%). Our program, then, reads a new note, then mixes 35% of the new value with 65% of the last note value. This slows and smoothes the transition between notes. If you'd like a faster transition, you can increase the MixPercent constant value.

This is a fun program to play with, but you really need to be careful with voice selection on your MIDI keyboard. Some voices sound great; some are just horrible. You can, of course, expand on the program by adding a second ADC0831 for volume control as with our keyboard program. Or, you could use a couple of sonar or IR-range finders as control inputs. The possibilities are wide open.

Before I leave this program, I'll answer the question that a few of you are asking yourselves: Why did I use PBASIC 2.0 programming style when all the cool new features of PBASIC 2.5 are available to me? Because the 2.0 syntax made the program easier to read and was a direct reflection of my program flow-chart (yes, I still do that — and you should too). Don't believe me? Well, here's what that program looks like using PBASIC 2.5 syntax:

```
Main:
  DO
    DO
       GOSUB Get_Note
     note = (note */ NMix) + (last */ LMix)
    LOOP UNTIL (note <> last)
    IF (note <= HighNote) THEN
  SEROUT MidiOut, MidiBaud, NoteOn,note, velocity]
       PAUSE 5
    ENDIF
  SEROUT MidiOut, MidiBaud, [NoteOff, last, 0]
    last = note
  LOOP
  END
```

This works exactly like the code presented above but, in my opinion, is not nearly as easy to follow. My point is this: Just because we *can* do something, it doesn't mean that we *should*. A good programmer will always write clear, concise code, and the clearest code is not necessarily the fanciest.

Conditional Compilation

One of the neat new features of the new BASIC Stamp compiler is called "conditional compilation." What this allows us to do is to selectively compile portions of the program based on internal or user-created symbols.

Before we get to the details, let me show you something that's at the top of this month's MIDI programs:

```
#SELECT $STAMP
 #CASE BS2, BS2e, BS2pe
   MidiBaud     CON     $8000 + 12

  #CASE BS2sx, BS2p
   MidiBaud     CON     $8000 + 60
#ENDSELECT
```

As you know, $STAMP is an internal symbol that tells the compiler what version BASIC Stamp we intend to compile for. The conditional **#SELECT-#CASE** structure lets us analyze that symbol and set the MidiBaud constant accordingly. This is really convenient for programs that you may be sharing with others and you're not sure which BASIC Stamp they'll be using.

As you might expect, there is also an **#IF-#THEN-#ELSE** structure, as well. Let's look at another quick example:

```
#IF ($STAMP = BS2) #THEN
  #ERROR "You need a Stamp with SPRAM for this program."
#ENDIF
```

This should be pretty easy to understand: If the selected [or connected] BASIC Stamp is a BS2 and, therefore, doesn't have scratch pad RAM, the program won't run (like internal errors, user-defined errors halt the compiler and are flagged). The **#ERROR** directive works like **DEBUG**, but creates a standard Windows error dialog as shown in Figure 4. Pretty cool, huh?

It's important to understand that the compiler scans your program for conditional structures prior to the actual compilation process, so variables and program constants cannot be used in the conditional compilation expressions. For flexibility, the editor allows us to create custom symbols. The syntax is:

#DEFINE Symbol { = value }

If the optional value is not supplied, the compiler assigns the value of -1 (65535) which evaluates as True in expressions. If, during the evaluation of an expression, the compiler finds an undefined symbol, it will treat that symbol as defined with a value of zero (False).

Here's how we might use this new tool. Often, as we're developing a program, we'll insert **DEBUG** statements to track the progress of program variables. When everything is working, we can take them out since they just consume EEPROM space and slow the program a bit. The problem is when we make a substantial update to the program, we end up putting those **DEBUG** statements back in. There's another way. Let's start by defining a custom symbol:

```
#DEFINE DebugMode = 1
```

Then, at an appropriate place in our program, we can create this block:

```
#IF DebugMode #THEN
  ' put DEBUG statements here
#ENDIF
```

We can turn the DEBUG statements on and off by changing the defined value of DebugMode (1 for on, 0 for off). Another approach for removing a symbol is to comment-out the **#DEFINE** line. And don't forget that **#IF-#THEN** includes an **#ELSE** block for additional flexibility.

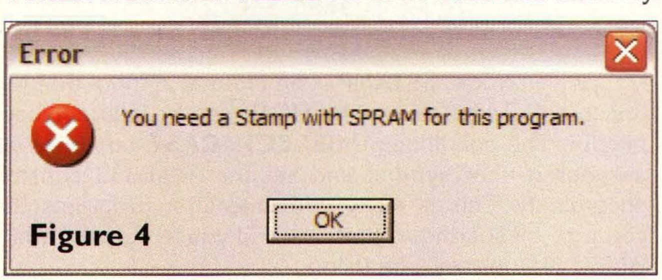

Figure 4

Space Saving

There's another new feature in PBASIC 2.5 that we can use to save EEPROM space. As you might know by now, long program lines that have comma-delimited lists can be split across multiple lines at the comma breaks. For example, this code:

```
DEBUG "The BASIC Stamp is an amazing microcontroller.", CR
DEBUG "I can't imagine my life without it!"
```

Can be changed to:

```
DEBUG "The BASIC Stamp is an amazing microcontroller.", CR,
      "I can't imagine my life without it!"
```

And we end up reducing the size of our compiled program by a few bytes because there is only one call to **DEBUG**. This works for **SEROUT** too because, in fact, **DEBUG** is **SEROUT** with the compiler setting the pin to 16 and the baud rate to 9600. Over the course of a program — especially with a lot of serial output — we can save enough space with this technique to make a difference.

If you have lots of long strings in your program, another space-saving strategy is to store them in **DATA** statements and call them when needed. I prefer to use zero-terminated strings so I can embed carriage returns in them. Like this:

```
Msg1  DATA  "The BASIC Stamp is an amazing microcontroller.", CR,
            "I can't imagine my life without it!", 0
Msg2  DATA  "My other car is a BASIC Stamp.", 0
```

Then we can send the string to any serial output with a simple subroutine. All we have to do is point to the string by setting the value of eeAddr before calling this code:

```
Print_String:
  DO
    READ eeAddr, char
    IF (char = 0) THEN EXIT
    DEBUG char
    eeAddr = eeAddr + 1
  LOOP
  RETURN
```

Storing strings in **DATA** statements makes them easier to find when making changes or translations too.

Okay, that's enough for this month. Happy Saint Patty's Day for those of you who share my Irish blood [on my mother's side] — and also to those of you who simply enjoy another reason to have a celebration. Sláinte (to your health!) and Happy Stamping! **NV**

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The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Design for Production

Producing a product in quantity and for profit is very different from putting something together for your own use. There are many factors that have to be addressed at the design level to make your product easy and cost-effective to manufacture. And, if you fail to do so, at the least you'll lose profit margin, at the worst you'll lose money. Testing, quality control, and assembly costs will be examined. You'll find that common sense and attention to detail are extremely useful.

SMT vs. Through-hole

Arguably, the most important factor is the PCB (Printed Circuit Board) layout. (This assumes that the PCB is the major component in the product.) The first thing to consider is through-hole or SMT (Surface Mount Technology). Through-hole is the more common procedure for hobbyist assembly. This uses leaded components and is easy for manual assembly. SMT uses leadless components (chip resistors, etc.) which can be extremely small and sometimes impossible to assembly manually.

Typically, SMT PCBs are assembled with automated pick-and-place machines and are soldered as a whole PCB in another machine. Generally, SMT is the preferred approach for production because it is usually more cost-effective than through-hole.

However, choosing between through-hole and SMT is not always a simple task. SMT requires a significant amount of production set-up time. Naturally, this costs money. Additionally, the SMT machines are expensive. So, a substantial up-front investment is required. On the other hand, SMT production can be extremely fast and extremely consistent. Through-hole assembly is slow and prone to human error. But, a soldering iron is cheap. And, there is no set-up time, so you can make 10 or 20 PCBs reasonably.

Note: It is possible and sometimes practical to use "large" SMT parts and hand solder them. A skilled assembler can solder ICs with 0.050" lead pitch (SOIC types) and discrete parts down to 0805 size using a standard needlepoint soldering iron without too much problem. However, re-work is difficult and slow. Getting smaller than this creates many problems. Special soldering irons ($500.00) are available for fine-pitch ICs (0.035" to 0.013" and getting even smaller). These are made for PCB re-work rather than assembly.

While such an approach may be feasible for a couple of prototypes, it's not practical for production. (The fairly new "Ball-Grid-Array" IC form factor is impossible to solder by hand because the solder balls are on the bottom of the IC and are simply not accessible with any manual tool.)

By the way, the thickness of a business card is about 0.013". Do you really think you can solder two leads this close together without shorting them? And, then repeat that for the other 98 leads on the 100-pin IC?

There are a few basic ideas to consider before you choose between SMT and through-hole designs. First: do not mix SMT and through-hole. Your design should be either all one or the other. A half-and-half mix is the worst possible choice. This requires BOTH machine and hand operations. It's the most expensive approach.

Sometimes, on a SMT PCB there simply are no SMT parts available (power resistors, displays, special connectors, etc.). If it's just a few parts, it's probably okay to go SMT. Do not put a few SMT parts on a through-hole PCB. Especially do not put a fine-pitch or ball-grid SMT IC on a through-hole board. Remember, a machine is used for SMT assembly. So, putting one or 100 SMT parts on a PCB means little to a machine. If you absolutely have to put a few SMT parts on a through-hole PCB, consider putting the SMT parts on the other side of the PCB. In this way, the machine can assemble and solder these parts as a separate operation. This is discussed in a little more detail below.

The second thing to consider is volume. Is your product going to be produced in 10s or 100s or 1,000s or 10,000s? The larger the volume, the greater the need to use SMT. If production is in the 100s, SMT should be the clear first choice. The more complex the design, the greater the need to go to SMT. A PCB with 250 parts should use SMT at a much lower volume than a PCB with 25 parts.

Another consideration is size/weight. SMT is generally smaller and lighter than through-hole designs. SMT can save substantial costs simply by reducing PCB size (remember you pay for PCBs by the square inch). Reliability is better with SMT. If your product needs to be repaired in the field, then through-hole may be better.

PCB Layout

How you lay out and route the PCB can have a significant impact on production cost and reliability. Use as large traces and spaces as possible. This makes PCB fabrication easier and less expensive. It also increases reliability by reducing shorted and open traces. (Generally, I try to use 0.020" traces and 0.015" spaces.) Additionally, wider traces yield lower impedance which improves high-speed performance and usually reduces EMI (Electro-Magnetic Interference).

Manually laying out the PCB takes time. But, if done properly, this can have a great impact on cost and reliability. Good PCB layout is sometimes more of an art than a science. First, the proper general placement of parts can be critical. The idea here is to keep all traces as short as possible. A good schematic diagram can go a long way in showing the proper parts relationship.

Note: It is best if the design engineer lays out the PCB. This way he can make simple design changes to ease the layout. For example, using different op-amps in a quad op-amp package may make layout easier. Or changing address/data lines to memory ICs. (It often doesn't matter if D1 of the RAM IC goes to D1 of the CPU as long as these lines are not used by a different part.) There are lots of these "tricks." Too many to be noted here. Just look at the circuit and the layout and determine what must be fixed and what can be changed. Then lay out the board with these aspects in mind. Sometimes — especially with embedded systems — simple software changes can simplify the layout, as well.

Orient common polarity-sensitive components (diodes, ICs, etc.) in the same direction. This means that all diodes have the "+" side in the same direction and all ICs have pin 1 in the same direction. (It doesn't mean that all diodes *and* ICs have the "+" side and pin 1 in the same direction.) This helps to prevent mistakes in assembly, testing, and re-work. You can orient components at right angles, too. But, again make sure common polarity-sensitive components are all oriented in the same direction.

When using discrete SMT parts (resistors, capacitors, etc.), try to select parts large enough for a trace to pass between the pads. This is important because it makes layout much easier and uses many fewer vias. (Fewer vias means slightly lower cost and increased reliability.) It should be noted that any discrete analog design that uses a through-hole approach can be accomplished with a single layer PCB. Virtually any analog design (using SMT op-amps) where a trace is allowed between the pads of discrete SMT parts can also be accomplished on a single layer PCB.

This gives you a choice. The first that you can use a cheaper single-sided PCB which doesn't require plated through-holes. This is probably only a significant advantage in large quantities.

The other option is to use the second side as a ground plane. This can significantly improve performance (reduce noise and EMI and allow increased speed). Note: Auto-routers generally fail miserably with single-sided designs. Additionally, they cannot tell the difference between high-current lines and sensitive input lines. This can lead to strange and difficult-to-find problems.

I've never found a reasonably-priced auto-router that worked well. Even the high-priced routers have problems. Note: This is not to say that PCB routers are bad. They can be useful. It's just that using this software removes your experience and knowledge from your design. Instead, you place your trust in a programmer you don't know and who may not know much about the practical aspects of PCB design.

PCB Layers

Unless you have a very complex digital design or noise-sensitive analog design, or are required to use very dense, high-pin-count ICs, you should be able to use an ordinary two-layer board (double-sided). In fact — in theory — any board can be routed using two layers. Going to four layers generally doubles the cost because a four-layer board is essentially two double-sided boards glued together. More layers are proportionally higher in cost.

If you need to put a few SMT parts on a through-hole board, it is often better to use the second side for these parts. This is because the wave-solder technique is usually used for through-hole parts and infrared (IR) reflow is used for SMT parts. Through-hole parts may not be rated for IR reflow heat. By placing the SMT parts on the other side, the through-hole parts are on the bottom during IR reflow. In this way, the PCB's shadow helps to protect the through-hole components from heat. Check with your assembler. They can give you specific guidelines for your specific situation. Putting a few through-hole parts on an SMT board is typical. This generally requires hand assembly and soldering of these parts. Obviously, the more parts, the greater the cost for this.

One layer that is often forgotten about is the silk screen. This layer can be extremely helpful for assembly, test, and repair. Don't be afraid to put notes on the silk screen. It doesn't cost any more. Label connectors with the function, as well as the reference designator (e.g., "J1 Serial Port"). I try to label the parts twice; once to be covered by the part during assembly, the second time for identification after assembly.

Labor Costs

Very often newcomers fail to understand that the most significant expense is usually labor. You can expect to pay $25.00 to $35.00 per hour for labor. This is the "loaded labor" cost which includes: salary, benefits, rent, heat, facilities, and everything else needed to support that person's job.

This means that soldering single wire can easily cost $2.50. Here's how. The wire must be retrieved from stock. It must be measured to size and cut. The ends must be stripped and tinned. Then the wire must be held in place while soldered twice (once for each end). Then, excess wire must be trimmed from the bottom of the PCB. Finally, the two joints must be inspected for a good connection. This can be expected to take at least five minutes. At $30.00/hour each minute costs $0.50. So, a five-minute manual operation costs $2.50. And, if heat-shrink tubing is needed (for example, on a connector), you can double this cost.

Obviously, this means that labor must be minimized. Use PCB-mounted switches and connectors. For manual through-hole designs, use a single more expensive part for multiple less-expensive parts. You must streamline assembly. Your initial design approach must target labor reduction as a major design goal. Take a look at common appliances and electronic products and see how labor is minimized. Overseas labor (including Mexico, et al) is much less than American labor. This is why many manufacturers assemble their products overseas. However, there are some problems with this. Generally, the lead times are long (months) and the quantities must be large. Then there is the added cost and delay of shipping (usually by ship!). There are always the problems of communication, documentation, customs, quality control, and testing. However, once these problems are worked out, great cost savings can be realized. (Just don't expect this approach to be painless.)

Testing and Quality Control

Production includes more than just assembling parts. Those parts must work properly. And, if they don't, it must be easy to fix. This is called "Design for Testing" and "Design for Quality." We won't get too specific here. There'll be other columns for these topics. In fact, books have been written on these concepts. Nevertheless, in the initial design stages, the ideas of production, testing, and repair should be examined.

If you are using an embedded processor, be sure to add special testing routines. Leave enough room between parts to connect test probes. Use the silk screen to label test points and even the voltage that should be there. The list can go on and on. The best approach is to think of yourself with an untested unit. What would you want to test it? What would make your job easier? If you think about this from the start, you can design a product that can be easily tested and repaired. Note that these statements apply to software, as well as hardware.

I have witnessed products that are virtually impossible to repair. For example, a product that requires complete disassembly to change a fuse. Or, through-hole ICs mounted over SMT parts so that access to the SMT parts requires the desoldering and removal of the through-hole part. Or, software without any notes or comments that uses obscure commands in peculiar ways to perform a simple operation. I'm sure that you have your own story, too. Don't make your product one of these failures.

Communication and Teamwork

We can see that the concept of Design for Production is something that must be considered at every stage in the product's development. This means — ideally — the same person should perform every function involved. But, it's not usually practical to have one person design the hardware, software, lay out the PCB, test, and produce a product. Instead, there is a specialist for each area.

Unfortunately, these specialists often tend *not* to talk to each other. This means that the hardware is developed without regard for software, software is developed without regard to testing, and so forth. This creates problems. Obviously, design for production suffers. But, additionally, the whole product suffers. Instead of an integrated whole, the product is made up of pieces forced to work with each other. This takes additional development time and can result in an inferior product. It is clear that teamwork is essential.

Everybody should be involved from the start of the design cycle. In this way, the production manager can identify potential problems before production starts. Hardware and software trade-offs can be decided much more easily. Testing and quality control become goals that everyone can see and understand.

Conclusion

Design for Production is a concept that tailors the development of a product so that production costs are reduced as much as practical. This provides the greatest profit margin. And, for any product, the larger the profit margin, the greater the chance for financial success.

The approach is really quite simple. At every stage in the design cycle, keep in mind that someone is going to make and repair the product. With that in mind, Design for Production becomes simple common sense. A little extra time and effort during the design phase can result in significant time and money saved on each and every unit that is produced. Doesn't it make sense to spend $5,000.00 worth of time once, in order to save $5.00 each on 10,000 units per year, every year? **NV**

QUESTIONS

I have a "Media Vision" CD player (Model: Memphis) with a nice set of detachable Bose speakers. However, the player is missing. I would like to connect the speakers to another audio source/computer, and I need the pinout of the DIN connector attached to the speaker cable. I believe Media Vision is out of business.

#3031 Andy Kochek
Thousand Oaks, CA

I've always enjoyed singing my own lyrics to popular songs (parodies). Karaoke's fine for this, as well as using the "difference channel" of the original recording. It would be a great kick, however, if I could hear the original artist sing my lyrics. Impractical as this may seem, in this computer age, though, I think it is possible.

My thoughts are along the lines of a DAW (Digital Audio Workstation) such as "Pro Tools" or "Digital Performer." Is there software available that can do this? A scenario might be, playing several of the artist's tunes into the computer's memory so it could "learn" the artist's vocal characteristics; then play the song you wish to parody — the lyrics come up on the screen, and you edit them to yours. The playback would now be the original tune, and the artist singing the new lyrics. Another way may be to sing the new lyrics yourself, and digitally have your recorded vocal characteristics altered to become similar to the artists. I think you get the general idea of what I'd like to accomplish. I'm unfamiliar with audio and musical software, as well as the capabilites of DAWs in general. If the readers can enlighten me, I'd be grateful.

#3032 John Agugliaro, CET
JAGUGL4546@aol.com

I'm looking for a very simple oscillator circuit that would operate off of three volts that could be varied in frequency by a variable resistor from 20-300Hz. It will power a small transformer to invert the voltage to 50 volts at very low mA.

#3033 James Dinsdale
Almagordo, NM

Is there any reader who has worked with A-to-D boards from Intelligent Instrumentation (was owned by Burr-Brown) who knows anything about a program that they used to sell called Visual Designer? I have an "evaluation copy" of this program which I have working with my A-to-D board, but they don't sell or support this program anymore and the "Help" file just doesn't get into enough detail with the problems I'm having trying to get the data the way that I want it.

#3034 Dale Blackwell
Brazil, IN

I have several Ademco Vista model burglar alarms made in the 1980s that send signals to central stations using a digital signal similar to a modem. I would like to use a computer and modem to receive this signal, but don't have any idea how to develop handshake signals. It is my understanding these are only 1200 or 2400 baud. Has anyone decoded the software?

#3035 Albert Balch
Seattle, WA

I have a remote control for TV, VCR, and other equipment made by Turtle Beach (a computer accessory company) that has the capability of also controlling X10 products. The setting for X10 is software controlled

This is a READER-TO-READER Column. All questions AND answers will be provided by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

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ANSWER INFO

- Include the question number that appears directly below the question you are responding to.
- Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address if responding by email or we can not send payment.
- Your name, city, and state, will be printed in the magazine, unless you notify us otherwise. If you want your email address printed also, indicate to that effect.
- The question number and a short summary of the original question will be printed above the answer.
- Unanswered questions from a past issue may still be responded to.
- Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

QUESTION INFO

To be considered

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

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

Information/Restrictions

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

Helpful Hints

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

and I need instructions on how to set the house code on the remote.

#3036 **Albert Balch**
Seattle, WA

I recently acquired a Mars-Tech hand scanner (model Mars 105). The end connector is a small eight-pin, DIN-type connector (about the size of a PS/2 end connector on a mouse). It has been said the end connector on the scanner might be Apple or Mac.

Does anyone know anything about the scanner? Is there anyway to convert or adapt the hand scanner to be used with a Dell table top running Windows? Can it be done without major surgery?

#3037 **Verl Wooters**
Centralia, IL

ANSWERS

[11021 - NOV. 2002]

I need a circuit diagram of an LCD display electronic compass that when going north would display an N on the screen, south a S, northwest as NW, southwest as SW. Or companies that supply kits.

#1 Check out Digi-Key's catalog online at **www.digikey.com**. They sell magnetic sensors. Manufacturer's links may turn up data sheets with sample circuits. You can also try using Google to search for electronic circuit and kits sites.

G. E. Brown
via Internet

#2 A "dead-reckoning" sub-system (one that retains its sense of direction) suitable for incorporation on robots is sold (and can be mail ordered) from JAMECO Electronics (in Belmont, CA). The preassembled unit is available for a very reasonable price.

Thomas Ng
San Jose, CA

[11022 - NOV. 2002]

I have a Raytheon RL9 Radar for a small boat made by JRC. The power supply board — H-7PCRD1331B CBD-1245 — has two pairs of power FETs for the oscillator which tested bad. The FETs are 2SK1112 and 2SJ239. The diagram of the power supply calls for a 2SK1306, but there is a 2SK1112 on the board. I need to find suitable replacements and a source for these two pairs of FETs.

Digi-Key (**www.digikey.com**) is a supplier with links to manufacturer's sites. International Rectifier's cross reference lists their IRL530N as a close replacement for the 2SK1306. Specs are: TO-220, n-chan, 100V, 17A, 0.10 ohm, fast switching, and logic level gate. The 2SK1112 cross reference is to a surface mounted part. Spec sheets available at the site.

G. E. Brown, via Internet

[12024 - DEC. 2002]

I have an IBM Thinkpad model 500 (2603) without a floppy drive. It uses an external floppy drive part #59G7918 with a cable #59G7925. I have a drive #41H7445 with attached cable. I think the drive would work if I could re-wire the cable and put another connector on it. Can anyone tell me if I can do this and how? Or am I stuck with using it without the floppy?

#1 I have an IBM Thinkpad 760, which uses internal plug-in floppy/CD/extra battery depending on which you wish. I have seen some of the other series that use the same floppy drive internally. I am not familiar with the 500 series, so I do not know if they have this feature or not.

I recently needed a replacement for the IBM and searched eBay, and found a suitable replacement. Mine had a mother board failure, but buying another 760 allowed me to swap the hard drive in my recently departed, and retrieve all the data, and continue with only a small hiccup in operation. I paid something like $150.00 for the complete computer. You might search for the specific drive needed. There were some computer floppy drives aftermarket a few years ago that plugged into the parallel port of the computer, and as long as you have the drivers, you could use them as if they were original equipment. I had a couple 5.25s several years ago, and they worked well. They would work on any computer as long as it had a parallel port, and they did not require a brand specific interface.

Ed Pruitt
Keller, TX

#2 The older IBM FRU #59G7918 floppy drive used in the IBM Thinkpad is a TEAC brand and has a Dell label and has been replaced by the IBM FRU #10H4056 external drive. TEAC also makes these for IBM, HP, etc. Different Thinkpads require different IBM cables, but usually if you're using this as an external drive or as a spare, you won't need a new cable. The best source for information on these external drives and cables, pricing and availability is at **www.facstaff.bucknell.edu/findeis/flopinfo.html**. IBM's toll free parts number is 800-388-7080.

Arthur Hazboun
Harbor City, CA

[2033 - FEB. 2003]

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

The information for the motherboard IrDA port can be found at **www.irda.org**. In particular, look at **www.irda.org/standards/pubs/IrDA_Dongle_V1p2.pdf**. The dongle includes electronics to convert the IrDA modulation scheme to the motherboard signal levels. The spec describes the signals on the motherboard connector, the external connector, and lists several possible

[2037 - FEB. 2003]

Has anyone interfaced a PIC with a standard ISA Ethernet network interface card so that no PC is involved? I had an idea that I could plug them into little roving gadgets. The whole thing would look something like an octopus (the body would hold the hub) on rollerskates.

#1 Yes, the PIC has been interfaced to ISA network cards by several people. One of the best descriptions I have seen was the article in the Oct. 2000 issue (#123) of *Circuit Cellar* magazine, pg. 12, by Edward Cheung. It interfaces a PIC 16F877 to an NE2000 compatible card. The article also cites several resources that will be helpful in such a project.

Be warned, connecting anything to Ethernet is not a quick or simple project. All the protocols required are rather complicated, especially when trying to shoehorn them into a small microcontroller. Pioneers such as Mr. Cheung have blazed the trail making it a little easier, but don't expect an easy project. *Circuit Cellar* has published many articles in the last several years on connecting microcontrollers to Ethernet and the Internet and I recommend you check their web site (**www.circuitcellar.com**) and there is a lot of relevant information on the web, just do a search for something like "Ethernet microcontroller" and you'll probably be overwhelmed.

William R. Cooke
Clarksville TN

#2 There are several web pages that describe how to interface PIC microprocessors to PC ethernet cards. My favorite is Simon Floery's "picnic" project which uses a 16F877 and standard NIC card to implement an embedded web server. Visit **http: //members.vol.at/ home.floery/ electronix/picnic/**.

While surplus NIC cards are easy to come by, I would recommend that you consider a design that interfaces the PIC chip directly to an ethernet controller IC. Fred Eady describes his "Packet Whacker" interface board which uses a Realtek's popular RTL8019AS at **www.chipcenter. com/circuitcellar/october01/c100 1fe5.htm**. Microchip sells what they call the PICDEM.NET demonstration board complete with TCP/IP stack and web server firmware. Even if you don't wish to spend the $200.00 for the demo board, you can learn alot about what it takes to support TCP/IP in a PIC controller at the PICDEM. NET web page. Visit **www.microchip .com/download/tools/picmicro/ demo/pdemnet/51240a.pdf**.

John Montalbano
Middletown, NJ
jrmont1@att.net

chips. (The IRDA connector on my old motherboard is different — it only has five pins: VCC, GND, TX, RX, and NC.

Most motherboards probably do not support FIR (fast data) rates. The 10-pin IrDA connector allows automatic configuration.

More information can be found in the IrDA Design Guide at **www.intel-u-press.com/usb_dbe/Chapter09/ IR/IRDAdg.pdf**. It provides information about hooking an HP HSDL-1001 to a motherboard (AKA SuperIO) IrDA port. See also the list at **www.intel-u-press.com/usb_dbe/Chapter09**.

The simplest thing to do is just buy an IrDA dongle and use standard OS drivers. The operation system drivers should handle the packet formatting, checksums, and interrupts. The dongle spec also describes interfacing a Consumer-IR transceiver, but I do not know how those devices are accessed from the operating system. Consumer-IR probably does not allow the reception of arbitrary remote-control codes.

Gerald Roylance
Mountain View, CA

[2035 - FEB. 2003]

I'm interested in producing power from a wind-driven generator. Should I use a large 32-volt DC Baldor motor that I salvaged from a golf cart? This motor is a shunt-type DC with an extra set of brushes (four brushes). The extra set must be for reverse?

I have spun the motor with a belt and another motor, but it doesn't produce electricity. I have disassembled the motor and it's possible to isolate the field from the armature. Is there a circuit to excite the field and turn this motor into a brute-force, blade-driven generator?

A DC motor that has its field winding connected to the same power rails as the armature, called "shunt wound," can indeed be used as a generator, yet it has some rather awkward characteristics. Speaking from recent experience, the output voltage is very sensitive to armature speed, and its start-up characteristic is dependent on the so-called "residual magnetism" of the iron in the pole shoes.

If it happens that residual magnetism is nonexistent, then spinning the armature will not produce any output current at all. A shunt-wound generator pulls itself up by its own bootstraps and so unless there is enough residual magnetism to create a magnetic field across the armature, even while the armature is not spinning, then it has no boot straps to grab hold of. For experimental purposes, you would be better off with separate excitation of the field winding, and that would also enable you to develop methods for controlling the generator output by controlling the current through the field with perhaps a transistor-based regulator circuit.

Once the field winding is isolated from the armature, you can excite the field with a battery in series with a rheostat. Check field continuity so that you know it will pass a current. Then monitor the voltage across the field while adjusting the rheostat.

With the armature spinning, the rheostat should give manual control of the generator output.

Jack Dennon, Warrenton, OR

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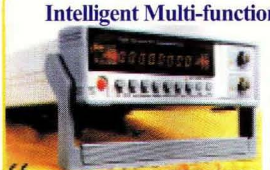

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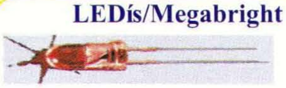

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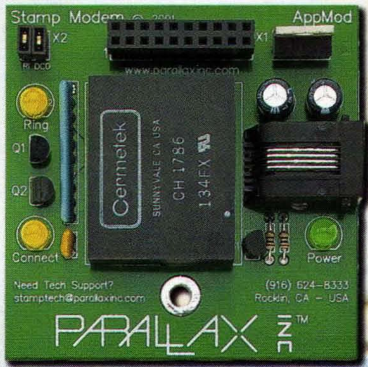

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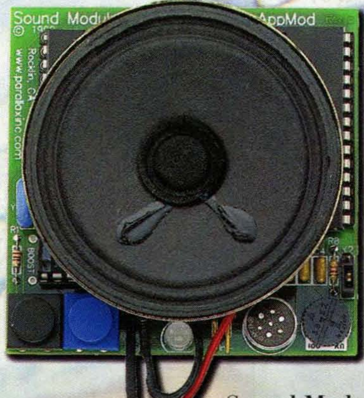

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