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Everything For Electronics

Nuts & Volts

May 2003

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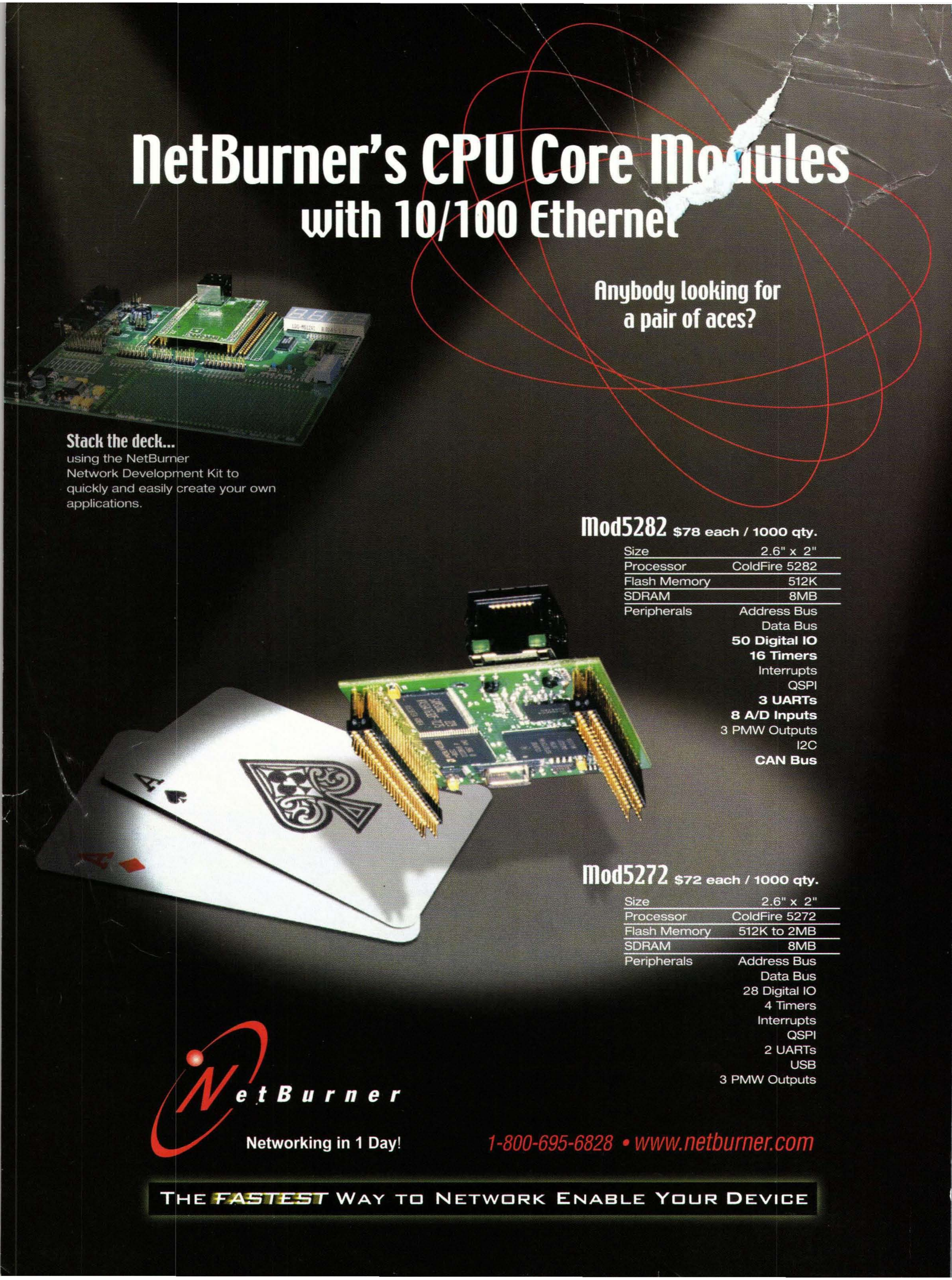
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DEPARTMENTS

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Dear Nuts & Volts:

I picked up my first issue of your magazine (Mar. '03) and was impressed with the articles and layout.

However, I was very disturbed by some of the remarks that were made in answer to the question about wiring a new house for phone and CATV (Electronics Q&A). The loss figures that were given are correct, but TJ Byers goes on to state to use a line amplifier then go in to two-way splitters.

As a licensed CATV and Telecom contractor, I do not fully agree with these remarks. The proper way to do this is to take *all* outlets — both CATV and PHONE — to a single common point that is close to the power panel so that *all* utilities can be common bonded (GROUNDED) to a single point (check National Electrical Code).

Use CAT5 or CAT6 cable for phones as this will give better protection from outside interference and will allow the use of high-speed data. Use RG-6 type cable and *not* RG-59 for the TV outlets as RG6 has a lower loss figure and ALL the cable company's are using it. If you install RG-59 and then call your cable company to install a cable modem, they will run a new RG-6 to that outlet, so save time and problems by using the RG-6.

Also, leave 8-12 inches of cable at the outlet box to install connectors and *do not* use RadioShack Type 2 or 3 piece or screw-on connectors. The cable tech will cut them off and install new compression types.

Good luck on the magazine

DJ
via Internet

Dear Nuts & Volts:

Jonathan Titus reads *Nuts & Volts!* (Mar. '03 Reader Feedback.) You see there, even the pros keep on eye on what you people are doing.

I built a Mark8 8008 computer from Jon's *Radio-Electronics* article a few

Continued on Page 36

From the editor:

Well so far, it's been a busy year at *Nuts & Volts*. We've changed formats, redesigned the look, absorbed *Poptronics'* subscribers, and are ready to go with the next Amateur Robotics supplement. And, in case you haven't heard, the Robot supplement will now be published quarterly, beginning in June. We've even added a few more pages to *NV* this month.

One thing we have noticed recently, is an increase in requests for specific article topics. Probably coming mostly from the *Poptronics* people, who are used to a little different editorial mix. In any case, we thought it would be a good time to formally open it up for requests, criticisms, comments, or whatever. We want to know what types of projects you want to build, what kind of tutorials you need. Any industry info you're interested in? How about the technical level? Want more beginner stuff, or harder, more advanced projects? Any thoughts about the magazine and how we can improve it are welcome.

Also, as we've mentioned elsewhere, what subjects (besides Robotics) would you like to see a supplement devoted entirely to? We've got a few on the drawing board, but your input could influence our decision.

We've set up a special email address for supplement ideas, but you can use it for *NV* editorial requests also. supplements@nutsvolts.com will get through directly to our editorial planning department.

On another note, this month will be the first issue that the *Poptronics* subscriber list will actually be merged with the *NV* list. Prior issues had to be processed separately because the two list formats were not compatible. As I write this, those who know more than I, are finishing up the conversion and preparing to merge and un-duplicate the two lists. They tell me that since some names and addresses are not entered exactly the same, they might not get caught in the "Merge/Purge" process. What that means is that if you were a subscriber to both mags, you *might* receive two copies. If, in your case, that unthinkable scenario occurs, just pass a copy along to a friend and let us know by email or phone. We'll take care of it and update your expiration date. subscribe@nutsvolts.com (800) 783-4624

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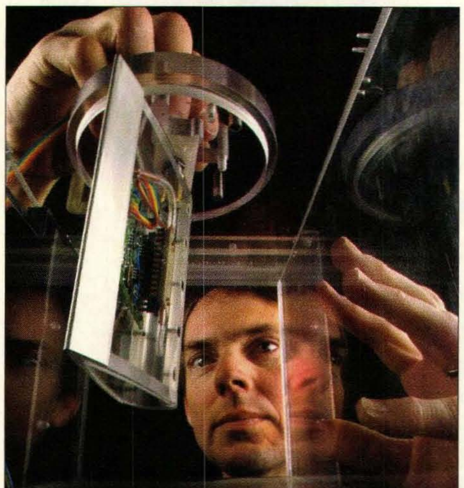
Advanced Technologies

Flying Electronic "Nose" Sniffs Out Noxious Gases



Sandia researcher, Doug Adkins, observes the wind tunnel performance of SnifferSTAR, a device intended to fly on drones and detect airborne blister agents and nerve gases. Photo by Randy Montoya, courtesy of Sandia National Labs.

A partnership between Sandia National Labs **(www.sandia.gov)** and Lockheed Martin Corp. **(www.lockheed martin.com)** has resulted in a half-ounce "sniffer" that is intended to fly on small drones to detect possible gas attacks on cities and military bases. The patented device, which detects nerve gases and blister agents, operates on only 0.5W of electrical power, and offers rapid analysis that was previously unavailable from any package in its size range. Immediate analysis is critical in warning an endangered population of an attack, and in surveying sites after alleged incidents.

Called SnifferSTAR, the invention consists of a series of tiny sensors on a platform about the size of a pat of butter, mounted atop a microprocessor board that is smaller than a credit card. The forward motion of the vehicle forces air through the device. Material in the sampled air is absorbed and concentrated, after which it is thermally released (desorbed) to pass over thin stripes of coating materials to which it temporarily attaches. The coating stripes are located on a quartz surface that vibrates at preset frequencies when small amounts of electricity pass through it. The mass of incoming attached particles changes the frequencies of the vibrations of each stripe.

The altered frequency data are passed to a processing unit on the SnifferSTAR module, and relayed to a processor on the drone or transmitted via radio to a main data processor on the ground. The information is automatically compared against a library of the patterns created by a range of gases. The sampling process can be repeated every 20 seconds, with 15 seconds intake and five seconds for analysis. The in-rush of air then clears the device sensors for the next reading.

Discussions are underway with a US company that produces drone aircraft to include the device, among sensors designed to detect biological and radiological threats. The device also has possibilities for use in or near the ventilation systems of buildings, or, with the addition of a small pump, on posts surrounding military bases and other sensitive sites.

Computers and Networking

New Standard Will Define MIDI Networking Techniques

The Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA) has begun work on a standard to extend the reach of the musical instrument digital interface (MIDI) by providing for MIDI transmission over Ethernet and IEEE 802.11 networks, which should be of significant interest to people who work in the music business. The new standard, IEEE P1639, "Standard for Transmission of Musical Instrument Digital Interface Data within Local Area Networks: Distributed MIDI (DMIDI)" should be finalized by the end of 2003. It will retain backward compatibility with existing hardware and software under the original MIDI specification, which is now 20 years old.

The original MIDI standard allowed for a transmission speed of 31.25 kbaud, which was adequate for controlling a few MIDI devices. DMIDI will use the current Ethernet-based networking structure to carry MIDI data at transmission speeds up to 10 Gbit/s. This speed boost will allow for the full use of such subprotocols as DLS and MIDI Show/Machine control.

The new standard will increase the number of addressable devices from 16 device channels to nearly 16 million, each retaining the existing 16-channel MIDI structure. DMIDI also adds the ability to send meta-messages for enhanced device control.

The standard will optimize DMIDI for low-powered devices, specify communication protocols for transmitting MIDI data in local area networks (LANs), and contain low-level protocols and high-level addressing schema for interconnecting MIDI-capable devices over LANs. It also will detail buffering strategies so that traditional MIDI hardware can deal with the higher transmission speeds, and so that software-based MIDI applications can coexist in the same networking domain as MIDI hardware, while running at full LAN speeds.

Anyone with a technical or manufacturing interest in MIDI is invited to join the IEEE P1639 Working Group. For more information on DMIDI, visit: **www.dmidi.org**/.

Free Teleconferencing Software Introduced

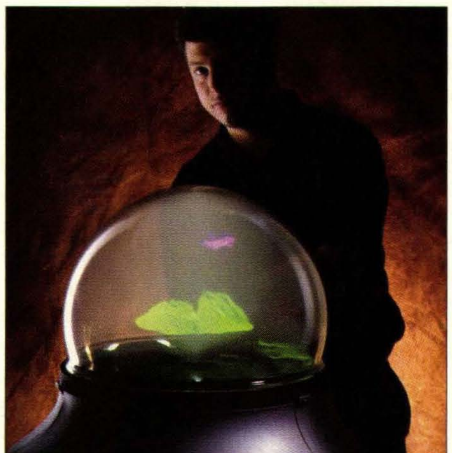
For years, we have been hearing about using PCs for teleconferencing, but the products have not lived up to anyone's expectations. A few weeks ago, a new company announced that it was taking a stab at making it work right. SightSpeed™, a product of QVIX Technologies, can be downloaded free of charge from the company web site, **www.sightspeed.com**. It is said to provide the highest quality IP-based video currently available, using an algorithm that delivers compression of 90:1 (as compared to 2:1 with CUSeeme and 15:1 with Microsoft's NetMeeting) and a latency of only 11 mS (compared to 450 and 250 mS with CuSeeme and Netmeeting, respectively). The result is an image delivered at 30 frames per second that is much less taxing to the human eye.

Before you get too excited, though, be warned that the program requires a CPU that runs at 500 MHz or better, 128 MB of RAM, and Windows 98/98SE/ME/2000/XP as the operating system. It is also recommended that you use one of the Logitech QuickCam Pro cameras. Others may or may not be compatible. In addition, you will need a DSL or cable modem connection.

Finally, although the web site does not provide specific information, it appears that you will be allowed to use the program for a limited number of minutes per day, with a clock ticking down while you communicate with your associates. Unlimited use will involve a fee, which appears to be $30.00 per month. Presumably, you will receive details after registering the product.

Circuits and Devices

Spatial Display Produces 3-D Images



The Perspecta 3-D System, a combination of hardware and software, permits 360° visualization, simulation, and collaboration. Courtesy Actuality Systems, Inc.

Offered as this month's "product you would love to have on your coffee table," is the Perspecta 3-D system from Actuality Systems, Inc. **(www.actualitysystems.com)**. The system consists of a 10-inch spherical display and associated Perspecta software, which together, enable users to render high-resolution spatial images and view them from any vantage point around the display.

The system is based on several patented technologies, including "rasterization of lines in a cylindrical voxel grid," which essentially covers a graphic algorithm that describes how to draw straight lines in multidimensional space, and a "volumetric 3-D display architecture," which encompasses the company's spinning-screen 3-D display and a projection screen that steers light in different directions to create photorealistic, solid-looking images.

Reportedly, it operates by projecting thousands of two-dimensional images on the screen, which rotates at 730 rpm. You get an image resolution of 768x768 pixels that refresh at 24 Hz. You get only three-bit color, but it is, after all, a new invention.

The unit illuminates 100 million volume pixels, or "voxels," within a transparent Lexan dome, and the images can be viewed without any special goggles. Intended applications include: nuclear medical imaging, such as using PET scans to locate tumors; medical intervention, such as planning radiation therapy; mammography and biopsy, such as having 3-D feedback on the precise location of a biopsy needle; drug discovery; air-traffic control; game development; and many others. The possibilities seem endless, especially if you can figure out a way to hook it up to a VCR. As you might expect, however, it is priced beyond the average family budget. According to reports in the trade journals, it starts at $50,000.00.

Power Supply IC Replaces Linear Transformers

Power Integrations, Inc. **(www.powerint.com)**, is now marketing a switching power supply IC that is designed to replace less efficient linear transformers in adapters and battery chargers rated at 3W and below. The LinkSwitch uses as few as 14 components to create a fault protected, universal input (85 Vac to 265 Vac), constant voltage, constant current (CV/CC) output switching power supply.

The LNK501 model is available in both through-hole and surface-mount DIP packages. The LinkSwitch combines a 700V power MOSFET and a PWM controller with high-voltage start-up, current limit, and thermal shut-down circuitry on a single CMOS chip. Requiring only three terminals, the device includes built-in features, such as thermal and current limit protection, auto-restart for short circuit and open loop fault protection, and the company's EcoSmart® technology, which is designed to reduce energy consumption during stand-by and no-load conditions. This enables engineers to design converters that meet government energy guidelines, such as Energy Star, Blue Angel, the EC Code of Conduct, and others.

Applications for the LinkSwitch include linear transformer replacement in adapters and battery chargers for a wide range of personal electronics (cell phones, cordless phones, PDAs, digital cameras, MP3 players, shavers), home appliances, television standby, and other auxiliary power supplies. Pricing in 10,000-piece quantities is about $.50 each. Small quantities of each type are available from factory stock, with production quantities available with about a month lead time.

Industry and the Profession

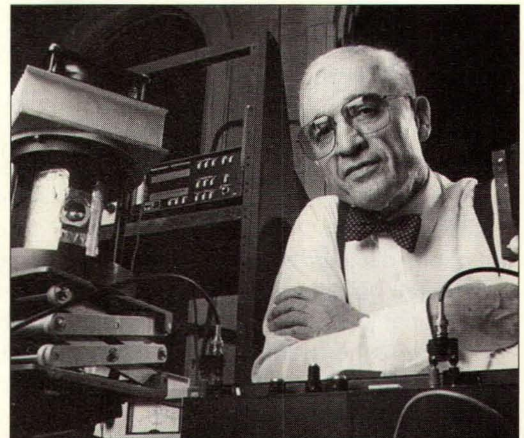
Holonyak Recipient of 2003 IEEE Medal of Honor

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

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

Before 1963, Holonyak worked for Bell Telephone Labs, where he helped develop silicon-diffused transistor technology. Several years later, while at General Electric, he invented the first practical light-emitting diode and the first semiconductor laser to operate in the visible spectrum. He also developed the first compound semiconductors in alloys known as III-V (referring to places in the periodic table of the elements) and the basic silicon device used in household light-dimmer switches.

During his career at the University of Illinois, Holonyak and his students demonstrated the first quantum-well laser, creating a practical laser for fiber-optic communications,



Prof. Nick Holonyak Jr., winner of the 2003 IEEE Medal of Honor.
Photo by Bill Wiegand, University of Illinois

compact disc players, medical diagnosis, surgery, ophthalmology, and many other applications. In the early 1980s, his group introduced impurity-induced layer disordering, which converts layers of a semiconductor structure into an alloy that has important electronic properties.

During the last decade, Holonyak and his students invented a process that enables the formation of high-quality oxide layers on any aluminum-bearing III-V compound semiconductor. The oxide process has had a major impact on vertical-cavity surface emitting lasers, making them practical for such applications as optical and data communications. His more recent research focuses on coupling quantum-dot lasers to quantum-well lasers.

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

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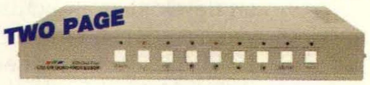

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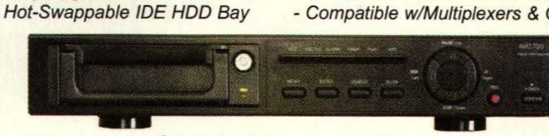

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Micro Memories

The Birth of X10 and the Dawn of Home Automation

Back in the Jul. '02 issue of *Nuts & Volts*, we looked at the rough-hewn Apple I. When Steve Wozniak was designing the Apple II, its classic successor, he was confident that one of the major applications for his new personal computer would be home automation, which lead to the Apple II's open design. Bill Berner and Craig Elliott, the authors of the 1996 book, *Approaching Home Automation,* speculated that open design was largely to facilitate the development of home-control devices.

However, Woz and his partner, Steve Jobs, didn't know that independently, a group of Scottish engineers were developing a home automation system of their own, called X10.

How X10 Got its Name

Today, most readers of *Nuts & Volts* probably take X10 for granted. (Except perhaps when confronted by one of their now ubiquitous, X10.com pop-up ads for their remote video cameras!) The fact that X10 modules can be purchased at RadioShack — which is to this day, still one of the biggest retailers of X10 products — has made X10 the McDonalds of home automation. But remote control of appliances and lighting through the existing power lines of the home was a major breakthrough in home automation in the mid-1970s.

In 1970, a group of engineers started a company called Pico Electronics, in Glenrothes, Scotland. Pico revolutionized the calculator industry by developing the first single chip calculator. (Most calculators at the time used at least five chips, known as Integrated Circuits — ICs.) Today, X10 claims that contrary to popular belief, this calculator IC was the world's first microprocessor. Pico went on to develop a range of calculator ICs, which were manufactured by General Instruments, and sold to calculator manufacturers such as Bowmar, Litton, and Casio.

When the price of calculator ICs began to plunge, Pico decided to focus on developing an actual retail product versus concentrating on just ICs. In 1974, the Pico engineers jointly with BSR, which at the time was the world's biggest manufacturer of record changers, developed a record changer that would select tracks on a regular vinyl LP. The Accutrac could be operated by remote control based on a device Pico developed using ultrasonic signals. This led directly to the idea of remotely controlling lights and appliances.

In 1975, the X10 project was conceived. It was the 10th project that Pico had worked on. There were eight different calculator IC projects and the Accutrac was project number nine. The concept of using existing AC wiring to transmit signals to control lights and appliances was born.

The Birth of Home Automation

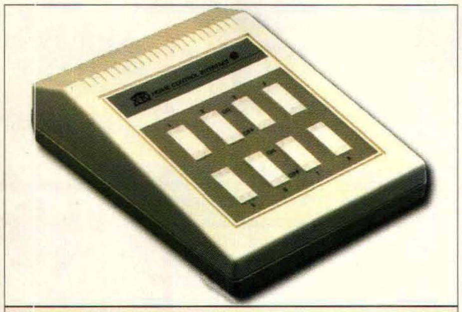
In 1978, after several years of refining their technology, X10 products began to appear in RadioShack stores, and shortly thereafter, in Sears. A partnership with BSR was formed, known as X10 Ltd., and the BSR System X10 was born. The system, at that time, consisted of a 16-channel command console, a lamp module, and an appliance module. Soon afterwards came the Wall Switch module and the first X10 Timer. While timers had long been available for electric lights, this was something new — a flexible home automation network which sent its signals through the existing power lines of a home. It's a fairly safe bet to call this the true birth of home automation.

The Perfect Combo: X10 and Computer Control

In the early 1980s, X10 lacked an official computer interface. Dave Rye of X10 says that "In the early days, there were a lot of computer enthusiasts using X10. There were third-party computer interfaces available even before we introduced one."

By 1984, Pico had developed a joint venture with GE for a product called the Homeminder. It was a VCR-styled package, slightly larger than a cable set-top box. It connected to the TV and was operated by an infrared remote. Eventually the GE division responsible for the Homeminder was closed and the units were repackaged and sold to RadioShack. Soon after completing the Homeminder, X10 developed their first computer interface for Mattel's short-lived Aquarius computer. X10's Aquarius computer interface eventually morphed, first into the RadioShack Color Computer Interface, and then into X10's long-lived CP-290 unit, a truly universal and extremely popular computer interface to control X10 modules.

X10's ActiveHome starter kit, which replaced their CP-290 controller. Still available to this day as an X10 to computer interface.



The CP-290 was an enormously popular X10 to computer interface.

It was also in 1984, according to Dave Rye, a vice president and technical manager with X10 (USA), Inc., that "BSR went belly up and so we pulled out in 1984 and formed X10 (USA), Inc. (we, being Pico). Pico is now a wholly owned subsidiary of X10 Ltd."

In 1989, X10 introduced the first low-cost, self-installed wireless security system. Then came the Voice Dialer security system, the Monitored security system, as well as Personal Assistance versions. In 1995, X10 set up its own monitoring station called Orca Monitoring Services in Seattle, WA. Today, it monitors security systems developed and manufactured by X10 for RadioShack, Philips Consumer Electronics (Magnavox), and the X10 Powerhouse brand.

The CP-290 was eventually phased out in the mid-1990s, when X10 replaced it with its ActiveHome controller. Over the years, the CP-290 had a long list of both "official" and shareware software so that it could be used with Apple IIs, Macs, DOS, and Windows in all of its many versions. Its incompatibility with the more finely-tuned dimmers that Leviton built into their X10-compatible switches was one of the reasons for the CP-290's obsolescence.

Whither X10?

At over 25 years of age, is X10 getting a bit long in the tooth? Of course. But Dave Rye is certainly optimistic about X10's future prospects, saying the format "will last forever. It is the de facto standard for home automation and is used by IBM, RCA, GE, Microsoft, RadioShack, Magnavox, Leviton and, in fact, just about everyone in the home automation business." However, over the years, there have been several attempts at replacing it. Two of these are CEBus (short for Consumer Electronics Bus), which was introduced in 1984, and in 1991, the Lonworks System. Both attempted to improve the reliability of the X10 system, but neither has (yet) caught on at the mass scale X10 has.

Helen Heneveld, a home automation industry consultant with the Training Dept. (**www.trainingdept.com**), which provides training products to the industry says, "In the early 1990s, the consumer mix fell into two categories: the ultra-high-end, with systems of $100,000.00 and up, and the mass market, with systems of $2,000.00 and $35,000.00. What actually happened was moderate acceptance of CEBus in the high market, and virtually no acceptance by the mass market."

Designed to go between a light socket and bulb, this module will control lights without a visible plug-in-the wall module.

In other words, while X10 isn't perfect, it's still the only modular system that can be bought on a low budget at RadioShack, Home Depot, Micro Center, and numerous other stores. And that ability to get started cheaply, for a homeowner to get their feet wet with home automation, is a very good thing. Now if only we could do something about X10's annoying pop-up Internet ads ... **NV**

by James L. Antonakos

Electronic Theories and Applications From A to Z

Let's Get Technical

Inside Protected Mode — Part 2

Protection and Multitasking

This month, I continue a multi-part examination of protected-mode architecture. Previously, the mechanics of segmentation and paging were covered. Here I will present the details of protection and multitasking — two very important features in multi-user and multi-process operating systems.

Protection

Consider a multiuser operating system based on the Pentium. Each user is capable of executing programs and using system resources, such as the hard disk, printer, and other hardware supported by the system. Now, imagine what might happen if one user's program goes out of control due to an unforeseen bug, and begins writing over important operating system data structures stored in memory, or even the code and data of programs being executed by the other users.

The system will, most likely, grind to a halt and require a complete reboot. Even worse, the problem may go undetected for a long time, causing additional bugs that may be hard to find when the initial problem is eventually discovered. This situation must not occur.

Through the use of certain protection mechanisms, this catastrophe can be prevented, and possibly even corrected, before any damage occurs. The Pentium provides protection for segmented and paged memory accesses. Protection is accomplished by comparing privilege levels during address translation. One task can be prevented from accessing code and data of another task, or even performing a task switch.

Protecting Segmented Accesses

Prior to any memory access using segment selectors, the Pentium performs five different checks. These checks are as follows:

- Type check
- Limit check
- Addressable domain check
- Procedure entry point check
- Privileged instruction check

Any violation of these protection checks results in an exception. Type checking is used to determine whether the current memory access (read/write) is allowed. For example, a memory write is not allowed on a read-only data segment. It may also be illegal to read from an execute-only segment. The types of accesses allowed are based on individual bits in the data and code segment descriptors. These bits include the writeable bit (data segment descriptor) and the readable bit (code segment descriptor).

Limit checking uses the 20 limit bits stored in the segment descriptor to guarantee that addresses outside the range of the segment are not generated. The granularity bit determines how the limit bits are interpreted.

When the granularity is zero, the limit bits specify the total number of byte addresses that may be used. For example, if the limit bits have been set to 01FFFH, no addresses above xxxx1FFFH may be generated. When the granularity bit is one, the limit bits specify the number of 4KB pages used by the segment. Thus, a limit value of 00400H represents a segment size of 1,024 4KB pages (a total segment size of 4MB). Any attempt to generate an

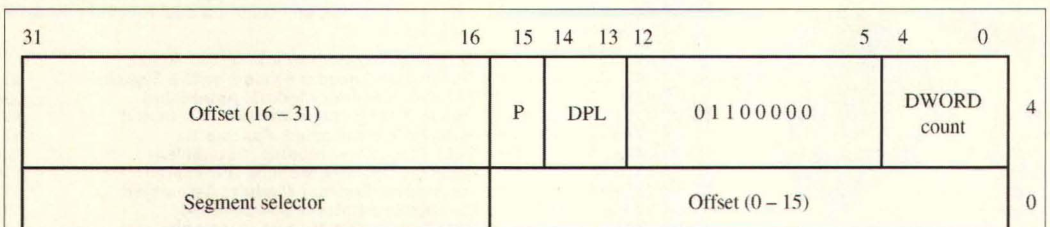


Figure 1. Structure of a call gate.

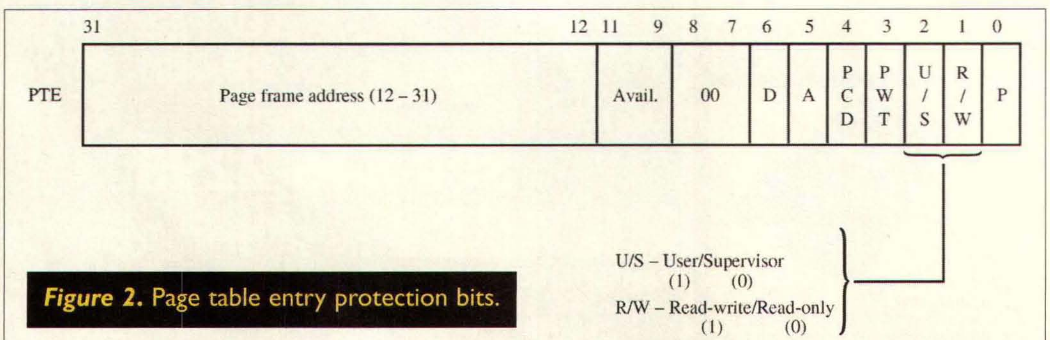


Figure 2. Page table entry protection bits.

address above the addressable limit results in a general protection violation exception.

The addressable domain of a task is a function of the task's CPL. A CPL of zero is the highest privilege level, and a task with a CPL of zero may thus access data operands in segments with any privilege level. As the CPL changes to lower privilege levels (one, two, or three), only segments with the same or lower privilege level may be accessed.

For example, a task with a CPL of two may access data segments with privilege levels of two or three only. A task with a CPL of three may only access data segments with a privilege level of three. The privilege level of a segment is specified by the two DPL bits stored in its descriptor.

The procedure entry point check is performed through the use of a call gate. Call gates are used to control the transfer of execution between procedures of different privilege levels. The structure of a call gate is shown in Figure 1.

The call gate has a structure similar to that used for a descriptor. The P (present) bit and DPL bits indicate the presence of the segment in memory and its privilege level. The DWORD count specifies the number of doublewords to transfer from the caller's stack to the stack in the new procedure, if there is a privilege change. The calling task's CPL is compared with the DPL of the call gate to determine whether control may be transferred to the procedure entry point specified in the call gate. Call gates are used by JMP and CALL instructions, and may only reside in the GDT and LDT.

Finally, some instructions are privileged, and may only be executed when the CPL is zero. These instructions include:

CLTS
HLT
INVD
INVLPG
WBINVD
LGDT
LLDT
LIDT
LMSW
LTR
MOV to/from CR
MOV to/from DR

A general protection violation exception is generated if an attempt is made to execute any of these instructions with a CPL greater than zero.

Page-Level Protection

Protection for memory pages is performed after the protection checks for segmented address generation, and consists of two checks:

- Type check (reads and writes)
- Addressable domain check (via privilege levels)

The page directory and page table entries (PDE and PTE) contain two bits that are used to perform these two checks. Figure 2 shows the format of a PDE or PTE. The two protection bits are U/S (user/supervisor) and R/W (read-write/read-only). Pages are marked as user (U/S equals one) or supervisor (U/S is zero).

A task is running at the supervisor level if the CPL is zero, one, or two. A task running at the user level (CPL equals three) may only access a user page. A task running at supervisor level may access any page.

When R/W is zero, the page is a read-only page. A user-level task may only perform reads from the page. No user-level writes are allowed. A supervisor-level task may also read the page. If write-protection is disabled (through the WP bit in CR0), a supervisor task may write to the read-only page.

When R/W is a one, the page is available for reads and writes. A user-level task may not read or write a supervisor-level page. If write-protection is enabled, the Pentium will catch any write to a user or supervisor page (via the page fault exception). Combining segment-level and page-level protections adds a large measure of security and reliability to a Pentium-based system.

Multitasking

One of the most significant features of protected mode is its ability to support execution of multiple programs (called tasks) simultaneously. In actuality, only one task is ever running at one point in time, since there is only one Pentium to execute on. But the ability to switch from task to task at very high speeds gives the impression that many tasks are all running at the same time. This is illustrated in Figure 3. Note that each task executes for a period of time (called a time slice), and then a task switch is used to switch from one task to the next. Rapidly switching from task to task gives the impression that all tasks are running at the same time.

The Task State Segment

During a task switch, the contents of all processor registers, as well as other information, are saved for the task being suspended and new information is loaded for the next task. This information is not saved on the stack, as you might expect, but in a special memory structure called the task state segment (TSS). The structure of a 32-bit TSS is shown in Figure 4.

The TSS contains storage areas for all of the Pentium's 32-bit registers and 16-bit segment selectors, plus additional storage for the stack pointers and segment selectors for each protection-level stack. When a task is created, the task's LDT selector (offset 60H), PDBR (offset 1CH), protection-level stacks, T-bit, and I/O permission bit map are filled in. During a task switch, these items are read, but not changed. Only the register portion (offset 20H through 5CH) is modified during a task switch, being overwritten by the current contents of each register. These values are read during a task switch that restarts a suspended task.

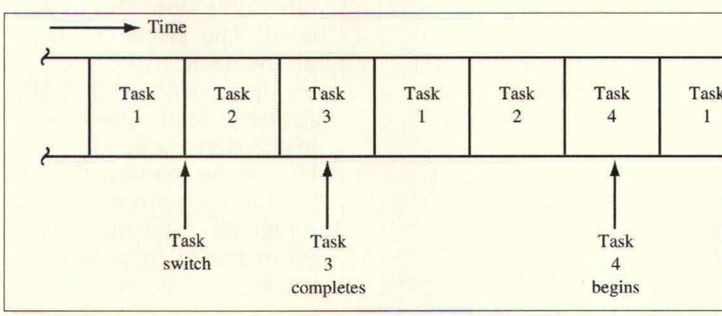


Figure 3. Running multiple tasks simultaneously.

TSS Descriptors

As with any segment, the TSS utilizes a descriptor that defines the various characteristics the segment will exhibit. Figure 5 illustrates the format of the TSS descriptor. The individual bit fields are defined as follows:

31–24	23	22–21	20	19–16	15	14–13	12–10	9	8	7–0	
Base address (24–31)	G	0 0	AVL	Limit (16–19)	P	DPL	0 1 0	B	1	Base address (16–23)	4
Base address (0–15)					Segment limit (0–15)						0

Figure 5. TSS descriptor.

Base address: 32-bit segment base address
Segment limit: 20-bit segment size limit
G: Granularity
AVL: Segment available
P: Segment present
DPL: Descriptor privilege level
B: Busy

The granularity bit determines how the limit field is interpreted (size in bytes or size in 4KB chunks). When G is clear, the limit field represents a segment size from one byte to 1MB. When G is set, the segment size goes from 4KB to 4GB (4,096MB, in chunks of 4KB). If the segment is available for use, the AVL bit will be set. The present bit indicates whether the segment is actually in memory or not (possibly having been swapped out during a page fault). The two-bit DPL field indicates the privilege level of the segment, and is used in protection checking. The busy bit indicates that the task is currently running, or waiting to run, when high.

The Task Register

TSS descriptors may only be loaded into the GDT. When multiple TSS descriptors exist in the GDT, the TSS currently in use is accessed through the use of the task register. The task register is used as an index pointer into the GDT to locate a TSS descriptor. The format of the task register is shown in Figure 6.

The task register contains two parts: a visible portion accessible by the programmer, and an invisible portion that is automatically loaded with information from the associated TSS descriptor. The task register may be loaded with a new TSS selector with the LTR (Load Task Register) instruction. LTR requires a 16-bit register or memory operand, and may only be executed in protected mode with a CPL of zero.

Initially, the task register is loaded with the first protected-mode task to execute via LTR. Then, during a task switch, the task register is changed to reflect the new TSS being used. The visible portion of the task register may be read with the STR (Store Task Register) instruction. Only the 16-bit selector portion visible to the programmer may be stored. STR may only be executed in protected mode.

31–16	15–0	
(Reserved)	Link (previous TSS)	0
ESP0		4
(Reserved)	SS0	8
ESP1		C
(Reserved)	SS1	10
ESP2		14
(Reserved)	SS2	18
CR3 (PDBR)		1C
EIP		20
EFLAGS		24
EAX		28
ECX		2C
EDX		30
EBX		34
ESP		38
EBP		3C
ESI		40
EDI		44
(Reserved)	ES	48
(Reserved)	CS	4C
(Reserved)	SS	50
(Reserved)	DS	54
(Reserved)	FS	58
(Reserved)	GS	5C
(Reserved)	Task LDT selector	60
I/O map base address	(Reserved) T	64

(shaded) – Reserved
T – Debug trap bit

Figure 4. 32-bit TSS structure.

Task Gates

Since the TSS descriptor contains two DPL bits that specify the privilege level of the segment, a task switch may result in a privilege violation if the new task has a lower priority than the currently executing task. In addition, it may be necessary for an interrupt or exception to cause a task switch to a segment containing the handler code. The Pentium provides task gates as an additional way to facilitate task switching. Task gates may be stored in the LDT of a task, or in the IDT (Interrupt Descriptor Table). The format of a task gate is illustrated in Figure 7.

Task gates allow a single busy bit to be used for a segment (the one contained in its TSS descriptor). Even though many different tasks might have access to a segment through their respective task gates, only one TSS descriptor is required for the segment.

For example, suppose that a TSS descriptor points to the handler code for the divide error exception. Since many different tasks may generate this exception, each will require a task gate in its LDT to access the TSS descriptor of the divide error handler.

Task Switching

Switching from one task to another is accomplished in four different ways:

Resources

Satisfy your curiosity by examining protected-mode material located on the web at:

http://x86.ddj.com/articles/pmbasics/

www.tenberry.com/web/dpmi/toc.htm

www.midpec.com/djgpp/protmode/

http://developer.intel.com/design/intarch/papers/exc_ia.htm

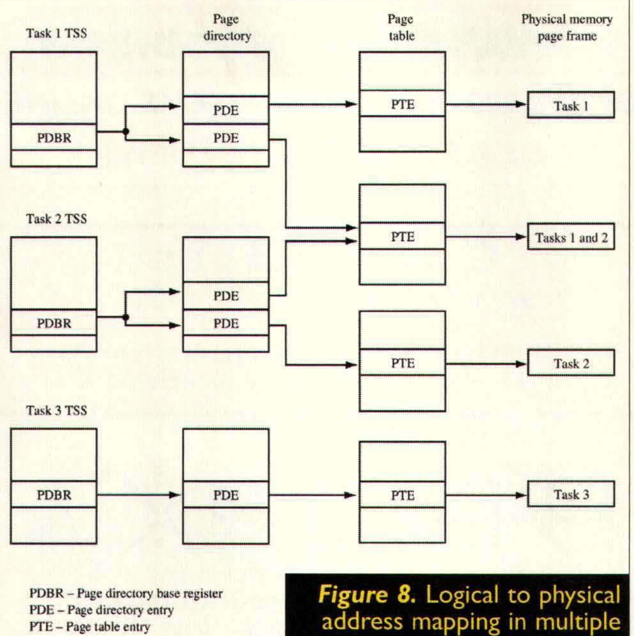


Figure 8. Logical to physical address mapping in multiple tasks.

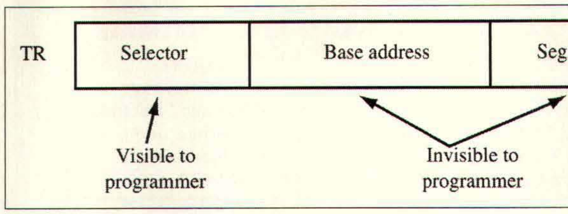


Figure 6. Task register format.

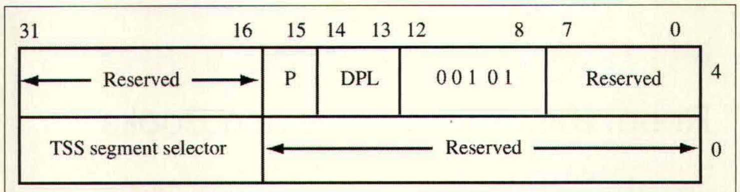


Figure 7. Format of a task gate.

- The current task JMPs or CALLs a TSS descriptor.
- The current task JMPs or CALLs a task gate.
- The current task executes an IRET when the NT flag is set.
- An interrupt or exception selects a task gate.

When a task switch is called for, the following steps take place:

1. The new TSS descriptor, or task gate, must have sufficient privilege to allow a task switch. The DPL, CPL, and RPL values are compared before any further processing takes place. Interrupts and exceptions do not force protection checking.

2. The new TSS descriptor must have its present bit set and have a valid limit field.

3. The state of the current task (also called its context) is saved. This involves copying the contents of all processor registers into the TSS for the current task.

4. The task register is loaded with the selector of the new TSS descriptor.

5. The busy bit in the new TSS descriptor is set, as is the TS bit in CR0.

6. The state of the new task is loaded from its TSS and execution is resumed.

The selector for the old task's TSS descriptor is copied into the TSS of the new task to facilitate a return when tasks are nested (NT flag is set). An IRET instruction checks the NT flag to determine if the previous TSS selector may be used during a task switch.

The TS bit in CR0 that is set during a task switch may be cleared by executing the CLTS (Clear Task Switched Flag) instruction.

Task Addressing Space

If paging is not enabled, the linear addresses generated by a task are the same as the physical addresses sent to the memory system. When paging is enabled, it is possible for each task to have its own separate, protected addressing space through the use of the PDBR stored within each TSS.

As Figure 8 indicates, tasks may map their logical addresses into different, or overlapping, physical memory spaces. Overlapping (or shared) physical addresses is useful for providing the same information to many different tasks (such as the contents of DOS's interrupt vector table).

More to Come

In Part 3, I will complete my coverage of protected mode features with a discussion of exceptions and interrupts, input/output operations, and Virtual-8086 mode. An actual protected-mode assembly language program will also be presented. **NV**

James Antonakos is a Professor in the Departments of Electrical Engineering Technology and Computer Studies at Broome Community College, with over 26 years of experience designing digital and analog circuitry and developing software. He is also the author of numerous textbooks on microprocessors, programming, and microcomputer systems. You may reach him at **antonakos_j@sunybroome.edu** or visit his web site at **www.sunybroome.edu ~antonakos_j**.

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Basics For Beginners

Just For Starters

Understanding Telephone Systems

This month, we are going to look at some basic information about phone systems. You may want to do your own house wiring, or may need to interface a project with the telephone. Understanding the operation of the phone system can help avoid problems, or make troubleshooting easier.

Tip, ring, and sleeve refer to the parts of a standard 1/4-inch plug (see Figure 1), and is a holdover from the days when operators actually used patchcords to connect callers together. Today, you will find that the terms in use deal with phone-related equipment and patch panel phasing.

In phone terms, it relates to keeping your polarity straight so that the ringing voltage and the holding voltage appear on the proper terminals of your equipment. It used to be that nearly all phone-related equipment was polarity-sensitive, and simply would not work if the polarity was reversed. As I mentioned in an earlier column, equipment today is much more forgiving. However, if you have a problem with a phone or equipment designed to attach to a phone line, you may find that correct polarity is required. To help keep things straight, the phone companies adopted a standard color code many years ago. Figure 2 shows the standard color code for house wiring.

Tip and ring are brought from the local telephone central office (CO) to each user's telephone equipment. When the user's tip and ring reach the CO, it is converted from two to four wires. This means that the send and receive audio are separated so the CO can process the two sources of audio independently. The information is then sent — usually digitally — to other COs by cable, microwave, or satellite.

At the CO, the telephone company places a DC voltage across tip and ring. A trickle charge battery bank that keeps the system operational during power outages usually provides this DC voltage, varying from 20 to about 48 volts DC. This system provides the direct current upon which the telephone set itself functions.

When a call is made, a ringing voltage of 105 volts AC, or pulsating DC, is provided by the CO to drive the ringer inside the telephone. When you pick up the handset, the hook switch disconnects the ringer and connects the telephone set to the line. Actually, it is connecting what is called a hybrid circuit across the incoming line. This is what keeps separate the incoming audio that goes to your earpiece from your audio coming from the microphone part of your handset. This keeps your voice sounding lower in your earpiece than the incoming caller. Hybrids can be used in several audio applications and we will have a column showing how to make one at a later date. They are used, for instance, in patching ham equipment to a phone line.

Anyway, getting back to what happens when you answer the phone. The hybrid will have a resistance of approximately 600 ohms. Anytime a DC path of 1,000 ohms or less is provided across tip and ring, the CO will sense this and will do two things. It will stop sending the ringing voltage and it will complete the connection to the incoming caller.

When a call is completed, another sequence of events is triggered. When you hang up your handset, you are, again, placing the ringer on the line and removing the hybrid. This change in resistance is detected at the CO as a current change, and is the signal to the CO to terminate the call. The CO will place your line back in the "standby" position and wait for the next call.

On the other end, certain other events will take place. The CO — having sensed a disconnect on your end — will send a momentary polarity reversal to the phone with whom you have been connected. This signal tells that phone, and their CO, that the call has been terminated.

In the case of automatic answering machines, computers, fax machines, and the like, it is this polarity reversal that tells the machine to terminate the call on their end and return to standby mode. Their CO will also return their line to standby and they will, again, receive a dial tone if their phone is off the hook.

I want to point out that there are some other methods employed in certain areas and situations that won't exactly match what I have described here. However, in the vast majority of the US, the methodology described here will be what you find. **NV**

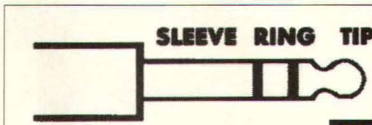


Figure 1

TELEPHONE WIRE COLORS

In the standard four-conductor house wire, sometimes called "I wire" for interior, red and green make a pair for line one and yellow and black make up the pair for line two.

TIP	RING
Green	Red
Black	Yellow

When you get into phone cables with more than four conductors, you will have a base color with another color painted on. This painted-on color is referred to as a trace and, in the case of the first conductor, the proper nomenclature would be, "white with blue trace."

TIP	RING
White/blue	Blue/white
White/orange	Orange/white
White/green	Green/white
White/brown	Brown/white

Figure 2

"Where It Is and How to Get It"

Robotics Resources

Inexpensive Microcontroller Options

Microcontrollers changed the face of amateur robotics. In one chip-sized package is an affordable programmable computer with a multitude of I/O for connecting to a robot's various motors and sensors. Best of all, they're cheap! Basic microcontrollers sell as low as just $1.00.

Microcontrollers are expressly designed to be used in so-called "embedded" applications, where control of some external device is the main goal. A huge advantage of microcontrollers over earlier approaches to robot brains — board-level computers — is that they are easily-connected, real-world devices. Based on the robot's input, the internal programming in the microcontroller can command the motors in such a way that the robot exhibits quasi-intelligent functions. For instance, the 'bot might move toward a light, or away from a barking dog. The possibilities are endless.

This month, we'll explore a variety of options for inexpensive microcontrollers. Though the microcontroller is basically a generic, universal device, some of these products are expressly designed for use in amateur robots.

Athena Microsystem Solutions

10624 Rockley Rd.
Houston, TX 77099 USA
www.athenamicro.com

Athena sells microcontrollers and single-board computer peripherals. Product highlights:

- AMS-HE/DE — Precision Hall-Effect DC current sensing module.
- AMS876 — SIMMStick plug-in module based on Microchip's PIC16F876 Flash memory microcontroller.
- SLI-OEM — Serial LCD controller.
- AMS-900PA/232 — Spread spectrum wireless transceiver.

Axiom Manufacturing, Inc.

2813 Industrial Ln.
Garland, TX 75041 USA
www.axman.com

Axiom Manufacturing specializes in single-board computers, embedded controllers, custom design, and manufacturing solutions. Products include single-board computers based on the Motorola 68HC11 and 68HC12 microcontrollers, 80CXX microprocessor, MPC555 PowerPC, and MMC2001 Mcore microcontroller.

Basic Micro, Inc.

34391 Plymouth Rd.
Livonia, MI 48152 USA
www.basicmicro.com

Basic Micro produces the MBasic line of compilers for PICmicro microcontrollers. Among their products are: development boards, getting started kits, ISP-PRO programmer, Atom and OEM Atom microcontroller, MBasic compilers, solderless development boards, prototyping boards, and ISP-PRO programmer.

The Atom-IC Module, available in 24- and 28-pin packages, is similar to the venerable BASIC Stamp, but with numerous hardware features that make it ideal for use in robots. The 24-pin version of the Atom is pin-compatible with the BASIC Stamp II, and the programming language used with the Atom is a superset of that found on the BASIC Stamp II.

BasicX

10940 N. Stallard Pl.
Tucson, AZ 85737 USA
www.basicx.com

The BasicX is a general-purpose microcontroller with a built-in programming language. You write programs on the PC using a Basic-like syntax, then download them, via a cable to the BasicX. Unplug the cable, and the program is now resident on the BasicX runs.

There are several flavors of the BasicX: The BasicX-1 is a 40-pin chip that requires an external crystal and capacitors, and voltage regulator (if one is not provided with your other circuitry). The BasicX-24 is a 24-pin chip that has everything on-board to run from a six- or nine-volt battery. The pinout of the BX-24 is the same as the BASIC Stamp II from Parallax. The BX-36 is a low-cost stand-alone chip version of the BX-24.

Blue Bell Design, Inc.

P.O. Box 446
Gwynedd Valley, PA 19437-0446 USA
www.bluebelldesign.com

Among its wares, Blue Bell offers a unique co-processor dedicated to robotics control. The co-processor adds servo control, A-D inputs, switch debouncing, and other features, and connects to your robot's main microcontroller.

Chuck Hellebuyck Electronics

1775 Medler
Commerce, MI 48382 USA
www.elproducts.com

Chuck resells the Atom from Basic Micro and MBasic compiler software. He also offers his own custom boards, as well. The BasicBoard is a general-purpose microcontroller board with LCD panel, speaker, LEDs, and other components built-in. It's designed as a get-it-working-quick solution for a variety of embedded tasks. The BotBoard is specifically designed as a robot controller and includes connection headers for R/C servos, A-D expansion ports, and more.

Dontronics, Inc.

P.O. Box 595
Tullamarine, 3043 Australia
www.dontronics.com

Dontronics specializes in microcontrollers, as well as the SimmStick prototyping development board system. Based in Australia, he ships worldwide. Highlight products:

- DT007 Micro Motherboard.
- DT104 Atmel Micro on a SimmStick.
- DT107 SimmStick for 8051, 8252, AVR 8515 and AVR 28 pin Micros.
- DT108 SimmStick Video.
- DT205 Relay Board.

- SIMM100 SimmStick compatible for the AT90S8535.
- Gigatechnologies USB.

Embedded Systems, Inc.
11931 Highway 65 N.E.
Minneapolis, MN 55434 USA
www.embedsys.com

Makers of low-cost development systems and add-ons for (among other things) Atmel AVR microcontrollers. Products include the AVR Sprint 2313 development system, AVR Sprint 2313 Basic starter kit, and AVR Sprint 2313 microprocessor module.

Gleason Research
P.O. Box 1494
Concord, MA 01742-1464 USA
www.gleasonresearch.com

Gleason Research sells the MIT Handy Board and Handy Cricket single-board computers. The Handy Board (see below) is a favorite at MIT, and many university and college robotics courses.

IndustroLogic, Inc.
3201 Highgate Ln.
St. Charles, MO 63301 USA
www.industrologic.com

Products include data acquisition and control devices, operator interfaces, and single-board computers.

Kanda Systems Ltd.
P.O. Box 200
Aberystwyth, SY23 2WD UK
www.kanda.com

Programmers for the following microcontrollers and sub-systems, including the 8051: Atmel AVR, CAN, Internet/Ethernet, Scenix, ST7, and Xicor.

Support for the Atmel AVR line is a specialty. Also sells starter kits, microcontroller chips and development boards, project boards, compilers and programming software (for both Basic and C), books, and PC interfaces. Additional offices in the United States.

Kevin Ross
P.O. Box 1714
Duvall, WA 98019 USA
www.kevinro.com

Kevin Ross sells a whole mess of BotBoard Plus microcontroller boards, and BotBoard interface products. Many of the boards are available in parts kit or assembled form.

The BotBoard Plus uses a Motorola 68HC11-based microcontroller and provides various connectors to attach robotic parts to it. According to Kevin, "The BotBoard Plus is widely used by universities and hobbyists for learning and experimentation. The members of the Seattle Robotics Society have been using the BotBoard design for several years."

Additional boards using other models of Motorola microcontrollers, such as the MC68HC912D60 and MC68HC812A4, are available as well. All are professionally produced, with green solder mask and plated-through-holes.

Kevin is also the editor of Encoder, the official publication of the Seattle Robotics Society (**www.seattlerobotics.org**).

Kronos Robotics
P.O. Box 4441
Leesburg, VA 20175 USA
www.kronosrobotics.com

Kronos has developed a line of microcontrollers called the Dios, where speed and low-cost are key features. The Dios line also supports code libraries of functions, which allow you to readily program the chip without having to re-invent the wheel. Additional products include various co-processor boards and adapter modules.

microEngineering Labs, Inc.
Box 60039
Colorado Springs, CO 80960 USA
www.microengineeringlabs.com

microEngineering Labs makes and sells development tools for the Microchip PICmicro microcontrollers. Some of their products:

- PicBasic Compiler — Compatible with the BASIC Stamp I, adds I2C support, instructions to access external serial EEPROMs, serial speeds to 9600 baud, in-line assembler code.
- PicBasic Pro Compiler — Compatible with the BASIC Stamp II, adds I2C support, direct and library routine access to any pin or register, automatic page boundary handling past 2K, real If..Then..Else..Endif structures, built-in LCD support to access more external devices including serial EEPROMs.
- EPIC Plus PICmicro Programmer — For Windows and DOS compatible, capable of in-circuit serial programming, parallel port interface, and works with most PICmicro microcontrollers.
- LAB-X1 experimenter board — Includes its own 20x2 LCD, 16-button keypad, serial port with nine-pin D connector, programmable oscillator, speaker, and more. Also offered is the LAB-X2 with less built-in hardware.

Microchip Technology
2355 W. Chandler Blvd.
Chandler, AZ 85224 USA
www.microchip.com

Microchip makes a broad line of semiconductors, including the venerable PICmicro microcontrollers. Their web site contains many datasheets and application notes on using these controllers, and you should be sure to download and save them for study.

Micromint, Inc.
115 Timberlachen Cir. Ste. 2001
Lake Mary, FL 32746 USA
www.micromint.com

Micromint offers single-chip controllers with built-in Basic interpreters, stackable controller boards, PicStic micro modules, miniature modems, and more.

National Control Devices
P.O. Box 455
Osceola, MO 64776 USA
www.controlanything.com

NCD offers microcontroller-enabled products useful in robotics. These include: A/D converters, character displays, graphic displays, input/output devices, I/O expansion modules, microcontrollers, motor controllers, relay controllers, and serial interface.

Many of the products are connected to a host (microcontroller, PC, etc.) via an addressable serial line, meaning you connect several of them on a single pair of wires, and talk to each one using its unique identification number. Up to 256 such devices can share a single serial port.

The owner of NCD wrote several articles for this magazine in 1998/99 describing practical uses for the products; the articles are reprinted for your edification at the web site.

NetMedia, Inc./BasicX
10940 N. Stallard Pl.
Tucson, AZ 85737 USA
www.basicx.com

NetMedia's BasicX family of rapid development microcontrollers includes the BasicX-1, BasicX-24, and the BasicX-35, plus various development boards and serial LCD modules. The BasicX sports a Windows-based Basic language development platform, and the BX-24 product has the same form-factor and pinout as the Parallax BASIC Stamp microcontroller.

New Micros, Inc.
1601 Chalk Hill Rd.
Dallas, TX 75212 USA
www.newmicros.com

New Micros, Inc., is a leading manufacturer of single-board computers (SBC), peripherals, and support electronics. The company specializes in embedded systems and, particularly, the Motorola processor line.

Robotics is singled out as an ideal application for the company's line of DSP-based microcontrollers. As noted on their web site: "The DSP803 Mini is the perfect board for robotic applications. Small in size, offering many features. NMIN-0803 Mini Features: Memory 32Kx16, program Flash 512x16, program RAM 2Kx16, data RAM 4Kx16, data Flash 2Kx16, boot Flash, 10 I/O(s), eight channel 12-bit A/D six PWMs, one quadrature decoder, two timers, two external interrupts, one serial communication interface, CAN 2.0, A/B JTAG, input power: 7 to 9V DC (3.3V and 5V regulators on-board). With LCD interfacing, and two LED indicators."

Oricom Technologies
P.O. Box 68
Boulder, CO 80306 USA
www.oricomtech.com

Oricom develops PIC and OOPic-based robot controllers, as well as "Bot-CoPs" — co-processors for off-loading computation-intensive real-time tasks from main controllers in small robotic systems. Web site includes experimental project info, links, and articles.

Parallax, Inc.
599 Menlo Dr., Ste. 100
Rocklin, CA 95765 USA
www.parallax.com

The BASIC Stamp revolutionized amateur robotics, yet the concept is simple: take an eight-bit microcontroller, normally intended to be programmed in assembly language. Instead of requiring folks to learn assembly, embed within the microcontroller a language interpreter, so that it can be programmed in a simpler language, namely Basic. The BASIC Stamp is a PICmicro microcontroller with such a language interpreter. It also includes additional basic components so that it is completely self-contained, and runs just by applying power to it. A voltage regulator, crystal, and additional memory are mounted on the BASIC Stamp chip, which is the same size as a "fat" 24-pin integrated circuit.

While the BASIC Stamp is a main product for Parallax, they recognize that robotics is a central area of interest, so they also offer a number of robot-centric items, including robot kits (GrowBot and BOE-Bot), various sensor packages (line following, compass, etc.), and development boards. They also team up with third-party companies to offer integrated products, such as RF modules, video cameras, LCD panels, and sound modules.

Rabbit Semiconductor
2932 Spafford St.
Davis, CA 95616 USA
www.rabbitsemiconductor.com

Rabbit makes a popular eight-bit microcontroller and associated developer kits. The Rabbit system is known for its speed (minimum CPU speed is 20 MHz, compared to 1, 4, or 8 MHz of most other microcontrollers). In addition to bare controllers, the company also sells "core modules" such as the RabbitCore RCM2200 with Ethernet connectivity built-in. Technical documentation and other support documents (most in Adobe Acrobat PDF format) are available at the site.

Reynolds Electronics
3101 Eastridge Ln.
Canon City, CO 81212 USA
www.rentron.com

Rentron offers kits and ready-made products for the electronics enthusiast and robotmeister, including PicBasic and PicBasic Pro compilers, BASIC Stamp, Microchip PICmicro, Intel 8051 microcontrollers, remote controls, tutorials, projects, RF components, RF remote control kits, and infrared kits and components.

Robotics Building Blocks
2639 West Canyon
San Diego, CA 92123 9212 USA
www.rdk2001.com

RDK sells Atmel AVR microcontrollers and robotics kits (minibot, Micro Mouse). The site provides useful examples of using the AVR with the BASCOM AVR Basic language compiler.

Savage Innovations/OOPic
www.oopic.com

Manufacturer of the OOPic and OOPic2, microcontrollers that offer multi-tasking and built-in "objects" that simplify programming. Many of the objects are directly suitable for robotics. Sold by distributors.

See also **www.oopic2.com**, **www.robotprojects.com**.

Systronix
555 South 300 East
Salt Lake City, UT 84111 USA
www.systronix.com

Embedded control hardware, software, enclosures, components, etc. Java and non-Java systems (such as JStamp), high-speed 8051s.

TECEL
216 34th St.
Ogden, UT 84401 USA
www.tecel.com

Microcontroller boards using 80C251, 80C552, 8051, and 68HC11 controllers. Compiler, assembler, and loader software included upon purchasing any of the microcontroller boards.

Technological Arts
819-B Yonge St.
Toronto, ON M4W 2G9 Canada
www.technologicalarts.com

Technological Arts produces postage-stamp size single-board computers using the Motorola 68HC1x microcontrollers. A number of special-purpose application boards are also offered, and many are suitable for robotics. These boards include:

- Voice record/play
- Display/keyboard
- X-Y-Z stepper
- X-Y stepper
- Data acquisition
- Quad 12-bit DAC
- 8-channel differential amplifier
- CAN interface
- Quad motor driver

The Handy Board
www.handyboard.com

The Handy Board uses a Motorola 68HC11 microcontroller to build a sophisticated robotics central brain. The Handy Board is used in many college and university robotics courses (it was originally developed at MIT), and is suitable for education, hobby, and industrial purposes. As the web site says, "People use the Handy Board to run robot design courses and competitions at the university- and high-school level, build robots for fun, and control industrial devices."

The features of the Handy Board are:

- Motorola 68HC11 microcontroller
- Two-Line LCD
- Integrated 700mAh ni-cad rechargeable battery (not included in some versions)
- Eight analog inputs
- Nine digital inputs
- Infrared output and input
- Start and stop buttons
- Piezo buzzer
- 32K battery-backed memory to store programs
- Four (1.1 amp) H-bridge motor drivers (not included in some versions)
- Serial (RS-232) and SPI interfaces

A great deal of documentation, user-supplies programs, and other material exists to support the Handy Board. But one of the best is a book by the Handy Board's creator, Fred Martin. Check out *Robotic Explorations: A Hands-On Introduction to Engineering* (ISBN 0130895687).

Zorin Microcontroller Products
1633 4th Avenue W.
Seattle, WA 98119 USA
www.zorinco.com

Makers and sellers of HC11-based embedded microcontroller systems. Products include: ModCon Microcontroller — Modular Controller; Digital Input and Event Processing System — Take actions based on sensors, push buttons and other inputs; SPI-X10 Controller — Control lights and household appliances; Audio record/playback — Record and play back up to 90 seconds of audio; MIDI gizmo — An easy way to interface the HC11 to MIDI. **NV**

Gordon McComb is the author of the best-selling *Robot Builder's Bonanza* and the Robot *Builder's Sourcebook*, both from Tab/McGraw-Hill. If you'd like to suggest a topic or resource, please send your comments to robots@robotoid.com.

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:

Several readers have very good thoughts and ideas that add to my response about CATV cabling before plastering the walls. Into vintage tube radios? Here are two common fixes. A couple of minor circuits dealing with lamps and audio signals, and a family of low-voltage audio power amplifier ICs.

PWM Fine Tuning

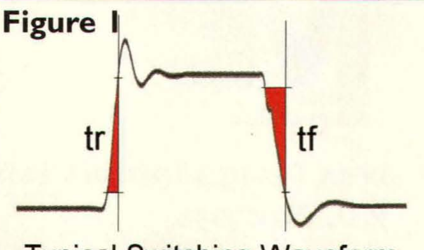
Q. I want to control the speed of a DC brush motor (rated 12 volts at one amp) using PWM with an FET as the power driver. At the present time, I plan to use a 1-kHz signal with a 30% to 60% duty cycle (300 uS-600 uS with a 1 mS period) to control the motor's speed. My question: How do I determine the optimum frequency of the PWM? Would it be better to operate the PWM at 3 kHz? And, if so, why would it be better: efficiency, power dissipation, power consumption?

Anonymous
via Internet

A. The ideal PWM controller combines high-speed power MOSFETs with low-switching frequencies to achieve extremely high efficiency in a very small package. The reason for this seemingly contradictory arrangement is to minimize the amount of time the power transistor spends in the active region. When a MOSFET is switched from off to on, the transistor doesn't respond instantly. It takes time to make the transition, during which the transistor wastes power and dissipates heat. This region is highlighted in red in Figure 1.

The less time spent in the regions of tr and tf (the red areas), the more efficient the controller. These times are a function of the MOSFET itself, and are specified in nanoseconds on the datasheet. As for the slower repetition rate, the fewer times the MOSFET has to make these transitions, the fewer watts wasted as heat and the more efficient the controller. Of course, the repetition rate has to be high enough that the motor response time doesn't mimic a battleship in a U-turn.

Figure 1



Typical Switching Waveform

That said, what is an optimal PWM frequency? It depends on the motor, the starting load, and a lot more. Most commercial PWM controllers for DC motors, of about 1/10 HP and thereabouts, run between 5 kHz and 15 kHz.

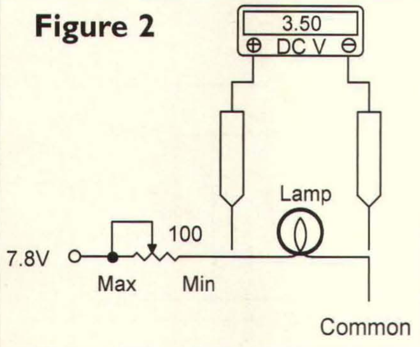
Hands-On Resistance Calculator

Q. I have a jukebox with many small bulbs — each receiving about 7.8 volts — that are starting to burn out simply because of old age. A cheaper alternative to replacing them is string "Christmas" lights, which are rated at 3.5 volts each. What size resistor do I need to make the voltage get closer?

Tim Fitzpatrick
via Internet

A. I love old jukeboxes and until recently, had one in my den from the 50s, so I know the problem with replacement bulbs. The way to determine the correct resistance is to put a 100-ohm pot in series with the Christmas lights, wired as shown in Figure 2. Set the pot to maximum resistance and adjust it down until the voltage across the lamp reads 3.5 volts. Remove the pot and measure its resistance. That's the value of the fixed resistor you want. Don't worry if the resistance falls between standard values. Simply use a fixed resistor with a value that's close enough. For example, if the potentiometer's resist-

Figure 2



ance is 66 ohms, use a 68-ohm 1/4-watt fixed resistor.

If you have room for them, I'd put two Christmas lamps in series, instead of using the voltage-dropping resistor. Instead of dissipating the power as heat alone, it becomes added light.

Audio Signal Indicator

Q. I need a circuit to monitor nine low-level audio signals with nine LEDs. For example, when there is a signal on input one, LED #1 lights up, when there is a signal on input two, LED #2 lights up, and so on.

Joe
via Internet

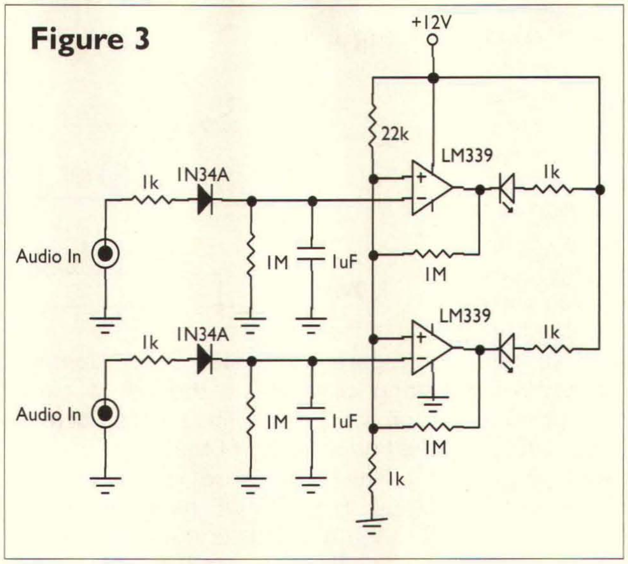
A. A simple way to do this is with a comparator, like the LM339 (Figure 3). The audio is rectified, filtered, and input to the inverting input of the comparator. A 1M feedback resistor introduces a small amount of hysteresis and prevents oscillation. The reference voltage is approximately 0.5 volts. When the audio level exceeds 0.8 volts (a typical preamp audio level), the LED lights. Because of space limitations, I've only drawn two channels. Simply duplicate the circuit to increase the channel count.

Super Scope Buys

Q. I am a hobbyist with an interest in BASIC Stamp projects. I would appreciate your recommendation for an oscilloscope that would fit these projects. Price is important to me, so if you could direct me towards used equipment, all the better.

Patrick McDowell
via Internet

Figure 3



A. I personally prefer working with PIC chips, which have the same scope requirement: 20 MHz or better bandwidth and a vertical sensitivity of 5 mV. A built-in frequency counter is helpful, but not mandatory. For most of my work, I use the osziFOX, a handheld PC-based scope about the size of a conventional test probe. Unfortunately, it's only sensitive down to about 250 mV. Which is why I have a JDR Instruments model 2000 bench oscilloscope — that I bought on an eBay auction for $56.00 — for more serious work. In fact, eBay is a good source of used electronic test equipment; today's auctions included over 200 listings for Tektronix oscilloscopes alone, many selling for under $100.00.

Motorboating Radio

Q. I have an old Minerva radio — at least that's what it says on the little plate just below what used to be a glass dial that runs across the top of the radio.

I would like to get this up and running, but have no schematic or even a model number to give you. It is a tube-type radio with six tubes and two rectangular cans mounted on the chassis. The front of the radio has three knobs: it appears that one is for on/off/volume and one is for tuning. The third, I don't know what it does. I'm able to get the filaments to light, but instead of music, I get a loud hum. I am sure that the capacitors are dried out and need to be replaced. Any help you can provide about this relic would be appreciated.

Ifostano
via Internet

A. It sounds like your antique is a typical AC/DC, superhet radio from the post WWII era. You can identify this breed by looking at the tube numbers, which should include a 35W4 and a 50C5. And you are quite right about the hum: the electrolytics are bad. However, the rectangular cans you see on top of the chassis are not electrolytics, but instead IF transformers. If you turn the chassis over, you'll probably find a paper electrolytic riveted to the chassis via a metal band. It may be a two- or three-section device (it contains more than one capacitor), which can be replaced with single electrolytics. However, you need to replace all the sections, even if only one is bad, because they share some parts in common and there is a good likelihood that the other sections will fail soon. The values typically range from 30uF to 80uF at 150 volts. However, finding an exact replacement isn't necessary. Any capacitance of equal or slightly larger value will work. Same for the voltage — equal or higher. Be sure to observe polarity and dress the leads with shrink tubing. A good source of tube-type replacement capacitors is Just Radios at **www.justradios.com/capkits.html**. By the way, your mystery knob is a tone control.

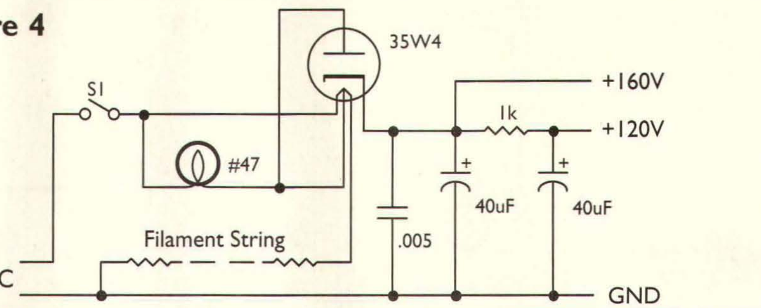
Not Just For Looks

Q. I have an old AA5 (All American Five) radio that keeps burning out the 35W4. Each replacement lasts for three months or less, and they aren't cheap. I don't have this problem with the other tubes in the set, so I assume there is something in the circuit causing this. Any ideas?

Jerry
via Internet

A. It's not something in the circuit causing the problem, but the lack of something. Specifically, the pilot lamp used to illuminate the tuning dial. To eliminate the power transformer previously used in tube radios, the filaments of the AC/DC sets are wired in series where the voltages of the filaments add up to about 112 volts. In the circuit shown in Figure 4, one side of the filament string connects to the circuit common which is the line running across the bottom edge of the diagram.

Figure 4



The other side of the heater string (the 35W4 filament) goes through a switch to the high side of the AC line. The #47 dial light also comes from this point to a tap on the 35W4's filament. By itself, the tap won't provide the 150 mA required to light the lamp, so the plate connects to the tap and adds its current to the mix. If the dial lamp burns out, though, the plate current now flows through the filament (about double its rated current), causing it to overheat and quickly burn out. The same arrangement is used with 35Z5 rectifier tubes found in older versions of the AA5. The solution to your dilemma? Immediately replace the $0.50 lamp if it burns out, or be prepared to keep shelling out $6.50 for rectifier tubes.

12-Volt Hum Filter

Q. I would like to build a filter or some other type of circuit that would remove the AC power hum from the charging/power circuit of a travel trailer power system. The travel trailer is used as a full-time home. The hum is affecting the 12-volt DC car radio/tape player. I have tried several store-bought filters, but none have even made a dent in removing the hum. Do you have some type of circuit diagram that will do the trick?

Kenny
via Internet

A. I assume you have checked all the ground connections for a ground loop that will cause what you describe. Ground loops are created when there's a resistance between two common ground points, like the stereo's case and the speakers. That said, let's see what I can do for you. Since brute force isn't doing the job, let's see if a little finesse will work. I suggest trying a fast transient response, low-dropout (LDO) regulator, like the LT1764 (available from Digi-Key: 800-344-4539; **www.digikey.com**), to remove the ripple. The circuit I've devised in Figure 5 supplies three amps of current with good ripple rejection up to 10 kHz.

In an effort to remove as much of the gross ripple as possible, and increase the IC's ripple rejection, an LC low-pass filter is placed in series with the 12-volt line ahead of the regulator. The 22-uF output cap is critical to performance, which means it should be tantalum instead of aluminum or ceramic. As always, pay attention to lead dressing, making sure the wire gauge is large enough to handle the current with little loss and that the splices are tight and clean. Hope this helps.

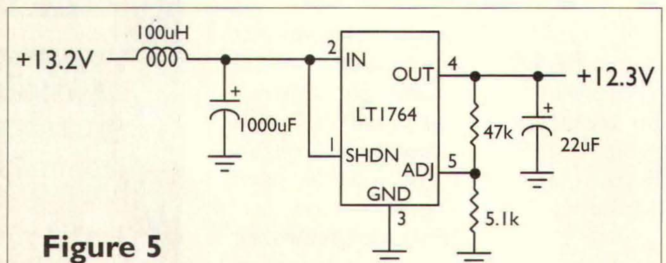


Figure 5

Increasing Speaker Volume

Q. I have a sound chip that drives an eight-ohm speaker through a

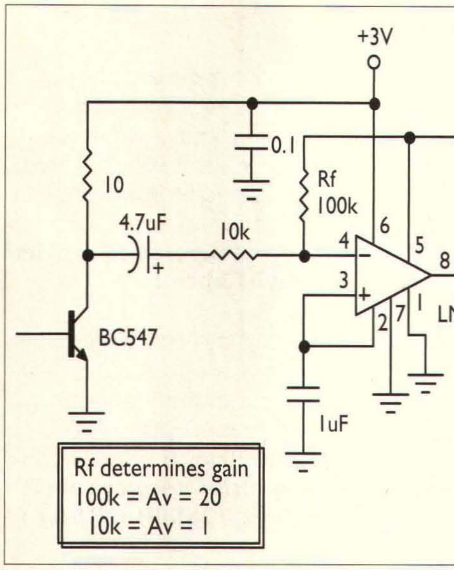


Figure 6

BC547 transistor. I want to increase the volume from the speaker. The speaker is connected to the collector via a three-volt supply, the base is driven by the sound chip, and the emitter is connected to ground. I have tried to use an LM386N to amplify the signal from the collector, but have not been successful. Is there a simple circuit I can use?

Ed Larson
Truckee, CA

A. You have the right idea, but the wrong part. The voltage range of the LM386N is 5V to 18V, which means it won't run off a three-volt source. A better power amp for your application is the LM4861, which sells for $1.74 from Digi-Key. The LM4861 is a member of the Boomer power amp series from National Semiconductor with an operating voltage range of 2V to 5.5V. With an eight-ohm speaker, the output power is about 1/4 watt (Figure 6). Substituting a four-ohm speaker will boost that figure to about a half watt; increasing the operating voltage to five volts doubles the output to 1.1 watts.

The gain of the amplifier is controlled by Rf. With the values shown, the gain is 20, which I assume is what you need for your project. If that's too little or too much gain, you can adjust the value of Rf up or down, respectively. Notice that the original speaker has been replaced with a 10-ohm fixed resistor.

MAILBAG

Dear TJ:

Concerning the "Wire Before You Plaster" answer in the Mar. '03 issue, my only suggestion would be to use the latest cable you can find, such as quad-shielded RG6. This would reduce loss and allow you to be ready for digital and HDTV — or whatever the newest craze becomes. As far as cabling for the telephone circuits, I would suggest CAT5E or CAT6 cable, again to keep up with whatever may come out in the future. It is far easier to do the job when exposed than to try and retrofit later. A good site for information on residential wiring is **www.bicsi.org**.

Tom Martin
BICSI Certified Instructor

Dear TJ:

I am a service technician in the cable television industry, and I noticed some things about your response to a reader question in the Mar. '03 issue that I feel you left out. As you stated, cable loss is very important, but I would like to add a few thoughts to yours.

First, with the new age of broadband and cable Internet and telephony, these services utilize a return path back to the cable company. The return path of the signal is important for broadband services like Pay Per View. Any splitters or amplifiers that are added should be able to pass the return signal back to the head end of the cable company. Not all of them will.

As far as cabling goes, the common practice now is to have each wall outlet return to a central location with a cable of its own (home run). This eliminates the possibility of a failure of one of the passive devices, a timely and costly troubleshooting/repair procedure. The cable should be aluminum shielded RG6/U. Also the fittings and connections have become very important due to the high frequencies. Most cable television systems have digital and analog television signals, which have gotten up to just around 900 MHz. The higher the frequency, the more critical the issues I mentioned become.

Randy Rains
Tacoma, WA

Dear TJ:

I read your response to the question regarding wiring a house for TV service in the Mar. '03 issue. Permit me to make a few observations.

The initial question used the term "coupler" to describe the device that divides one incoming signal into multiple output signals. You used the term "splitter." There are two types of devices that can be used here: splitters and directional couplers. A directional coupler style splitting arrangement is preferred (in my very humble opinion) for the reason that it provides much higher isolation between each output. Very important, especially in an environment where multiple TVs will be on at the same time.

Another issue is proper termination of each feed. If you take a piece of coaxial cable, connect one end to a splitter output, and leave the opposite end unterminated, you have created a fairly hefty shunt capacitance across the line. Using simple splitters, this will cause problems for the entire system. And if the cable length happens to be just right, there will also be reflections (or ghosts) that show up on the other sets on the unterminated line. A directional coupler will help minimize these types of losses.

The trade-off is that directional couplers cost more than simple splitters and they have higher losses.

Jerry McCarty
via Internet

Cool Web Sites

The BIOS keeps track of the most integral PC system settings, and serves as a sort of preflight check when you first boot. This article explains how to optimize your BIOS.
www.cpuplanet.com/features/article.php/1570371

Whatever Visual Basic programming experience you may have, learning about ActiveX could improve your career, your bank balance, and your love life.
www.developer.com/net/vb/article.php/1539541
www.webreference.com/programming/activex.html

A definite trend in the electronics of today and of the future is interconnectivity. Not all communication needs are complex, explains Robert Ashby. A must for engineering and programming students.
chipcenter.com/eexpert/rashby/rashby070.html

Are you just getting into SPICE simulation of analog circuits, or are you an old hand at it? Check out this site for both introductory tutorials, as well as advanced pointers.
http://email.e-insite.com/cgi-bin2/flo/y/eLJH0EijIq0DaS0Bu1C0A1

NEW LCD TV KIT, COMPLETE WITH TUNER AND SPEAKERS IDEAL FOR EMBEDDED VIDEO SOLUTIONS

Earth Computer Technologies announces a new addition to its lineup of video-compatible LCD kits. The new 12.1" LCD TV kit fills the need for smaller displays required in consumer and professional applications, including automobiles, recreational vehicles, surveillance, and museums.

Optimized for full-motion video, this super-thin display combines high resolution, a crisp image, and robust audio quality in a turnkey LCD kit. The SK-3006 kit consists of multiple options for input, XGA, composite, S-video, and NTSC. This combination of connections allows a user to connect a computer, cable, satellite, or DVD player, then choose the desired input through the remote control. The remote control adjustments include channel up/down, volume up/down, mute, sleep mode, input selection, and many more options.

"By foregoing the traditional enclosure on the LCD TV and offering it as a kit instead, it opens up a whole new set of options to suit just about any embedded video application," says Steve Cipolla, General Manager of Earth Computer. For additional information, contact Jennifer Coleman at 949-248-2333 extension 223.

EARTHLCD
32701 Calle Perfecto
San Juan Capistrano, CA 92675
949-248-2333 ext. 223 Fax: **949-248-2392**
Email: **jennifer@earthlcd.com**
Web: **www.earthlcd.com**
Circle #36 on the Reader Service Card.

NEW DIGITAL BENCH METER MODEL M-5500

Elenco's Digital Bench Meter M-5500 (M-5500-R) is a meter that can be used on the bench or in the field by technicians and students.

This is a true RMS for interpretation of AC voltage/current waveforms. The backlighted LCD display allows viewing in low-ambient light levels.

Model M-5500 features: Large digital display 3-3/4 (3,999) count, 42-segment display; Auto/manual ranging method; Storage data display recall; Data hold maximum/minimum; True RMS for AC voltage/current; Continuity test (audible); Backlighted display; Portable or bench with pop-up stand, carrying strap included; Compartment to store test leads or other accessories. Optional power: operates on 120 VAC or DC (nine-volt battery or six AA batteries) not included.

For additional information, contact:

ELENCO ELECTRONICS, INC.
150 W. Carpenter Ave. Wheeling, IL 60090
847-541-3800 Fax **847-520-0085**
Web: **www.elenco.com**
Circle #37 on the Reader Service Card.

NEW! HIGH-TECH SPY-TECH SPY TRACKER

Never get caught! Leave no trace! Detect intruders anywhere! This extreme surveillance Spy Tracker System comes with three sensors and a base station/receiver. Sensors can be placed anywhere, have a transmission range of 75 feet, and even work through walls! The base station offers visual and audible warning signals and a markable map-grid that allows you to plot out surveillance parameters with the included dry-erase marker.

Everything stores neatly in one compact and highly mobile carrying case. The Spy Tracker requires eight 'AA' batteries (not included).

Spy Tracker #30818-96 is available for $26.95.

For more information visit our web site at **www.ScientificsOnline.com**.

SCIENTIFICS®
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Fax: **1-800-828-3299**
Web: **www.ScientificsOnline.com**
Circle #38 on the Reader Service Card.

DATABOY

Micro Contraptions announces DataBoy, a low-cost RS-232 serial comm data scope (protocol analyzer) cartridge that runs on a Game Boy.

DataBoy can capture and display two channels of asynchronous serial data (RXD and TXD). In a typical application, it might be used to troubleshoot serial communication problems between a PC and a serial device such as an external modem or a plotter.

Some of the features are listed below:

- Selectable serial comm parameters.
- Capture/display RXD and TXD data.
- ASCII and hex display modes.
- Review captured data in freeze mode.

- Send captured data to a PC or serial printer.
- Send a message to test a receiving device.
- Selectively assert DTR, DSR, CTS, and RTS.
- Help screens.

Its small size and rugged construction makes DataBoy suitable as a field service tool while its low cost is affordable to hobbyists.

The price of a DataBoy cartridge plus RS-232 cable is $149.00.

For more information and an interactive Java test drive, visit the DataBoy website.

MICRO CONTRAPTIONS, INC.
1319 Cleveland St. Evanston, IL 60202
847-733-1311
Email: **Ytaraki@lycos.com**
Web: **www.databoy.netfirms.com**

Circle #39 on the Reader Service Card.

COMPACT VGA VIDEO SWITCH BOASTS RS-232, AUTOMATIC, AND MANUAL CONTROL OF SWITCHING

Hall Research Technologies (HRT) introduces the Model VS-2 VGA Video Switch designed to select one of two video sources to be displayed on one monitor. The VS-2 supports resolutions up to 1600 x 1200 with exceptional image quality. The fully solid-state switch terminates both input signals and features amplified output with a bandwidth of 250 MHz for a perfect image even at 150 feet.

The Model VS-2 can be controlled in many ways: manual, RS-232 serial port, discrete input, or set to "auto mode" to detect and switch to the input with active video automatically.

The device is housed in a small RFI shielded enclosure and includes a push-button control cable, as well as a serial (RS-232) control cable. Other features include: ability to blank the output, infinite switching life cycle, low cost, and easy integration with automated or touch-screen A/V control systems.

The VS-2 measures 4" x 3" x1" and weighs about one pound. The unit comes complete with control cables and power supply and is priced at $179.00 list.

For additional information, contact:

HALL RESEARCH TECHNOLOGIES, INC.
Marge Bitetti **1-800-959-6439**
3613 W. MacArthur Blvd., Suite 612
Santa Ana, CA 92704
Ph: **714-641-6607** Fax: **714-641-6698**
Web: **www.hallresearch.com**

Circle #40 on the Reader Service Card.

Continued from Page 6

months before *Popular Electronics* published Ed Roberts' article on the Altair, and so it is good to see that Jon has corrected the historical record. The 8080 in the Altair, of course, did for the 8008 the same as the 8088 would later do for the 8080; the upshot being that down here where us peons work, it's a real treadmill.

Jack Dennon
Warrenton, OR

Dear Nuts & Volts:

I really enjoyed the article "Random Number Device — Part 1," because of my interest in codes. I am looking forward to Part 2. As this article is somewhat esoteric, perhaps you would consider an article on Prime Numbers along with BASIC programs to find these numbers.

Stuart B. Wahlberg
Blythe, CA

Dear Nuts & Volts:

I was a subscriber to *Popular Electronics* and *Radio Electronics* and I have issues back to the 60s. I used to pick up *Nuts & Volts* when I lived in California. I just got my second copy today and I am impressed, you've come a long way. I hope you will be around for a long time.

Francis E. Wissler
via Internet

Dear Nuts & Volts:

I just wanted you to know how much I appreciated Ray Green's article on serial port utilization in the April *NV*.

When my copy arrived, we spent the class period using it as the perfect example of what we've been studying in my Architecture & Interfacing of Micro-computers course. We had just done an experiment on interfacing via the Game Port where we controlled a stepping motor's speed, direction, and on-off by keystrokes. The students had to put together the lines of code (in Basic) to do this, so you can imagine how they resonated with the material in your article. Of course, we did PEEKs and POKEs instead of IN and OUT.

I wish there would be more articles where the author was willing to include detailed explanation of how things worked, as well as just how to build it so it would work. That teaches some transferrable skills. Great job!

C.D. Geilker/Professor
Wm. Jewell College

by Jack Dennon

Random Number Device

One-Time Pad Encryption

PART 2

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!

The interface circuit that we presented in Part 1 permits any computer equipped with an RS-232 serial port to obtain real random bits from atmospheric noise. We programmed the IBM PC computer to assemble these bits into real random numbers.

Software presented in this concluding part uses these real random numbers to implement message encryption using the theoretically unbreakable "one-time pad" scheme invented in 1917 by Joseph Mauborgne and Gilbert Vernam.

Program Installation

The onetime.bas program, that can be downloaded from **www.seasurf.com/~jdennon**, is a "self-extractor" containing concatenated QBASIC sources for all the programs of this one-time pad encryption system. When we run this program with the command

```
qbasic /run onetime
```

it reads its own source file, onetime.bas, from which it extracts and writes to disk the QBASIC sources for the programs

```
anrng.bas
antest.bas
match.bas
msgin.bas
msgout.bas
rnhist.bas
```

and the ASCII text of the shell scripts

```
getmsg.bat
makehist.bat
makepad.bat
matchpad.bat
sendmsg.bat
```

System Set-up

Label an empty floppy disk for each user. If setting up the system for two users — such as Alice and Bob, for example — label one disk for "Alice," and the other for "Bob." Begin by copying onetime.bas to Alice's disk. Make that floppy drive the current disk and then call the self-extractor with the command

```
qbasic /run onetime
```

This will put a copy of all the QBASIC sources and all the shell scripts on Alice's floppy disk. We can then use the batch file makepad.bat to invoke the padfile generator, anrng.bas, with the command

```
makepad
```

The anrng.bas program asks for a "basename" for the padfiles. Enter, for example, the name

```
alice
```

The program next asks for the number of padfiles to be created. The program has pagesize set to 10, so the files created will contain 2,560 decimal numbers. Each number is one to three digits long, and each is followed by a carriage return and line feed. On average then, each number will occupy about four bytes, so the file size will be about 12k. There should be about 1.2 Megabytes remaining available on the 1.44 Megabyte floppy disk, and we are creating padfiles for two users, Alice and Bob, so each user can have about 600 Kbytes worth of padfiles. Assuming that each padfile takes about 12 Kbytes, we should be able to create 600K/12K = 50 padfiles for Alice and 50 padfiles for Bob. With a file count of 50, the program will run about 15 minutes and create padfiles named ALICE100 through ALICE149.

Padfiles for Bob

The floppy disk must also contain a set of padfiles for Bob, so again, use the command

```
makepad
```

and this time, for example, give the program the basename

```
bob
```

and a file count of 50. When this operation is complete, the disk will contain all the QBASIC program source files, and all the shell scripts, plus a set of padfiles for Alice, and a set of padfiles for Bob. We need to make a copy of this disk for Bob.

Make a Copy

To avoid leaving erased padfiles on the

No special tools or skills required. Be sure and take necessary precautions when working with electricity.

hard drive, we can use the DOS utility named DISKCOPY to copy Alice's disk for Bob. Diskcopy will leave an image of the disk in memory, but that image will disappear when the computer power is turned off. We just need to remember to do that before leaving the computer unattended. Make drive C: the current disk, and then enter the command

```
diskcopy a: a:
```

The DOS Diskcopy program will prompt for the "source" disk. Our source disk is the floppy disk we created for Alice. Diskcopy will copy the contents of that disk to memory, and then it will prompt for the "target" disk. Put Bob's disk in the floppy drive and hit Enter. When the Diskcopy operation is complete, we will have two identical copies of the floppy disk.

Key Distribution

Getting Bob's copy of the floppy disk to Bob is the set-up step that professional cryptographers disparage. Whether or not this so-called "key distribution problem" renders the one-time pad "impractical" is a question Alice and Bob will have to answer for themselves. The system is ready for use when each user has a copy of the floppy disk, and the system remains secure while the padfiles remain secret.

Accidental Edits

When a run-time error is detected, such as "file not found," QBASIC invokes its integrated text editor. This feature may seem more like a fault if you unintentionally hit a key that modifies your program. You can carefully exit the text editor without saving the modified code. Or to entirely lock-out the possibility of accidental edits, you can mark the QBASIC sources "read-only" with the command

```
attrib +r *.bas
```

This changes the "attribute" of each source file to read-only.

Protocol

When Bob encrypts a message to send to Alice, he should use one of his own padfiles, BOB100 through BOB149. When Alice, for her part, encrypts a message to send to Bob, she should encrypt the message with one of her own padfiles, ALICE100 through ALICE149. While Alice and Bob follow this protocol, the encryption and decryption programs themselves provide sufficient interlocks to keep track of which keys have been used and which are still available.

Run from Floppy Disk

Our padfile creation process wrote padfiles only to the floppy disk. We deliberately created the floppy disks in such a fashion that padfiles were kept off the hard drive where Eve might be able to find them. When we use the padfile floppy disk, we run with the floppy drive as the current drive. To do that, the shell COMMAND.COM must be able to find the path to your QBASIC interpreter. If your QBASIC package is in the \DOS subdirectory, for example, then your PATH environment variable, that can be displayed with the command

```
PATH
```

should echo a string that includes C:\DOS. If, for example, you are running in a DOS window on a Windows 95 system, and the PATH command echos

```
PATH=C:\WINDOWS;C:\WINDOWS\COMMAND
```

then type in the command

```
SET PATH=%PATH%;C:\DOS
```

to append ;C:\DOS to your path string.

Sending a Message

Mount the padfile disk in a floppy drive and then make that drive the current disk. When the shell script sendmsg.batis is called with the command

```
sendmsg
```

it runs the msgout.bas program listed below.

```
'msgout.bas: one-time pad rotor encryption
DIM rotor%(95)
newline$ = "`" 'define end-of-line char

c= 32  'first rotor character is space
FOR i = 0 TO 94
        rotor%(i) = c
        c = c + 1
NEXT i
PRINT

INPUT "name of the PADFILE to use: ", padfile$
OPEN padfile$ FOR INPUT AS #1
nk% = 0
DO      'find next available key
        INPUT #1, mykey%
        nk% = nk% + 1
LOOP UNTIL (mykey% <> 0 OR EOF(1))

INPUT "name of the MESSAGE file to create: ", msgfile$
OPEN msgfile$ FOR OUTPUT AS #2
WRITE #2, nk%              'point to first key
heading$ = padfile$ + " " + DATE$ + " " + TIME$
WRITE #2, heading$
msgtext$ = "" : msglen = 1: msgtotal = 0
PRINT "enter your message, end with a blank line"

DO
        LINE INPUT "message line:"; clrtext$
        clrtext$ = clrtext$ + newline$  'append end-of-line
        msglen = LEN(clrtext$)
        FOR i = 1 TO msglen
                cn% = ASC(MID$(clrtext$, i, 1))
                index% = (cn% - 32 + mykey%) MOD 95
                cipher$ = CHR$(rotor%(index%))
                msgtext$ = msgtext$ + cipher$
                INPUT #1, mykey%
        NEXT i
```

```
        msgtotal = msgtotal + msglen
LOOP UNTIL (msglen = 1)

WRITE #2,msgtext$
CLOSE #1
CLOSE #2
PRINT
PRINT USING "message contains ### characters"; msgtotal
SYSTEM
```

Practical Rotor

For clarity, the example rotor used for demonstration of rotor encryption contained only the upper-case alphabet. The rotor we actually use in the encryption and decryption programs includes all the printable ASCII characters.

Alice Sends a Message

The msgout program first asks for the name of a padfile. Alice can give it the name ALICE100, for example. The program then asks for a filename for the encrypted message, such as "TOBOB1." Alice can then type in her message, ending the message with a blank line created by hitting Enter at the beginning of the line. The program encrypts the message using, sequentially, the key numbers from the padfile, ALICE100, together with the 95-character rotor containing the ASCII characters space (32) through tilde (126). Each key number from the padfile is used to encrypt exactly one cleartext character of the message.

Check the Encrypted Message

Alice can verify that the message has been correctly encrypted by decrypting it with the command

```
getmsg
```

When asked for the message filename, Alice enters the name TOBOB1. The program will decrypt and display the message. The session may look like this:

```
getmsg
qbasic /run msgin
name of the MESSAGE file to decrypt: tobob1
kc% = 1

alice100: 11-07-2002 16:36:59
Mother Hubbard says
the cupboard is bare.

message contains  43 characters
You should now ERASE the padfile named alice100
and then rename PAGETEMP to alice100
```

When Alice is satisfied that the message is correct, she should erase the padfile ALICE100 and then rename the temporary file PAGETEMP to ALICE100. This step updates the padfile ALICE100 such that all used keys are removed.

Message File

The message file TOBOB1 will begin with a cleartext preamble that contains a pointer to the start of the keys used to encrypt the message, and a string containing the name of the padfile and a time stamp telling when the message was encrypted. The ciphertext following the header contains the encrypted message:

```
1
"alice101 11-07-2002 16:36:59"
"a*6|hGY+ZTMo!__(=[wvYq]* %1squ'}aqg\$i}Z'$5"
```

Both the cleartext header and the ciphertext of the message are composed entirely of seven-bit ASCII characters. The file can be transmitted via SMTP (email), FTP, UUCP, sneaker-net, or any other conveyance able to move seven-bit ASCII text from one place to another.

Message Decryption

When Bob receives the file TOBOB1, he can decrypt it with the command

```
getmsg
```

The shell script getmsg.bat runs the msgin.bas program:

```
'msgin.bas: one-time pad decryption
DIM rotor%(94)
newline$ = "`"        'define end-of-line char

c = 32  'first rotor character is space
FOR i = 0 TO 94
        rotor%(i) = c: c = c + 1
NEXT i

PRINT
INPUT "name of the MESSAGE file to decrypt: ", msgfile$
OPEN msgfile$ FOR INPUT AS #2
INPUT #2, kc%
INPUT #2, heading$
PRINT USING "kc% = ####"; kc%
'PRINT heading$
ksp% = INSTR(heading$, " ") 'find end of padfile name
padfile$ = MID$(heading$, 1, ksp%)
OPEN padfile$ FOR INPUT AS #1
LINE INPUT #2, msgtext$ 'read entire ciphertext
msglen = LEN(msgtext$)

kci = 1
WHILE (kci < kc%)
        INPUT #1, mykey%
        kci = kci + 1
WEND

msg$ = ""
FOR i = 2 TO msglen - 1
        INPUT #1, mykey%: kci = kci + 1
        cipher$ = MID$(msgtext$, i, 1)
        cipher% = ASC(cipher$)
        index% = cipher% - 32 - mykey%
        WHILE (index% < 0)
                index% = index% + 95
        WEND
        clrtext% = rotor%(index%)
        clrchar$ = CHR$(clrtext%)
        IF clrchar$ = newline$ THEN clrchar$ = CHR$(13)
        msg$ = msg$ + clrchar$
NEXT i
CLOSE #2
```

```
OPEN "pagetemp" FOR OUTPUT AS #2
FOR i = 1 TO kci
        WRITE #2, 0
NEXT i
DO      'now copy the unused keys to temporary file
        INPUT #1, mykey%
        WRITE #2, mykey%
LOOP UNTIL (EOF(1))

CLOSE #1
CLOSE #2

PRINT
PRINT heading$
PRINT msg$
'PRINT
msglen = LEN(msg$)
PRINT USING "message contains ### characters"; msglen
PRINT "You should now ERASE the padfile named "; padfile$
PRINT " and then rename PAGETEMP to "; padfile$
SYSTEM
```

End-of-Line

In order to create ciphertext that contains only printable ASCII characters, our rotor purposely excludes ASCII control codes. This does give rise to an infelicity — we must use some printable ASCII characters to mark the ends of text lines. The present programs define grave accent (`), in cleartext, as the end-of-line marker. When decryption yields this end-of-line character, the program emits a carriage return and line feed to the cleartext.

Remove Packet Header

If Bob received Alice's message via email, then he will probably have to remove the email transmission control information that encapsulates the message text. To do that, load the entire email file into the DOS editor with the command

```
EDIT TOBOB1
```

Put the cursor at the beginning of the file. Then hold down the Shift key while moving the cursor down to the line just above the message header. This will select all the email control text that precedes the message. Hit Delete to remove all the selected text. Move the cursor to the line just below the end of the ciphertext and use the same select and delete procedure to remove the email trailer text. The edited TOBOB1 file should now contain only the message header and the ciphertext:

```
1
"alice101 11-07-2002 16:36:59"
"a*6|hGY+ZTMo!__(=[wvYq]* %1squ'}aqg\$i}Z'$5"
```

Bob Decrypts the Message

Bob puts his copy of the padfile disk in the floppy drive and makes that drive the current disk. When Bob invokes the msgin.bas program with the command

```
getmsg
```

the program asks for the name of the message file. In this example, Bob would give it the name TOBOB1. The program reads the message preamble and extracts from it the name of the padfile that was used to encrypt the message —

Construction

Begin by cleaning the copper side of the printed circuit board. Use fine steel wool to burnish the tin-plated foil to make it bright and shiny. Use your small soldering iron 25 to 40 watts with pencil or chisel tip well tinned, and have handy your damp sponge with which to keep the soldering tip clean. Use small diameter (0.031") rosin core solder; 60/40 lead/tin is fine.

Install the 14-pin dip socket for the IC, taking note that the socket has an indicator for the location of pin 1. Tack-solder opposite corner pins on the socket, then pick up the board and, while pressing in on the socket, touch your soldering iron to each tacked pin and press the socket tightly against the board. Check orientation of the socket and then solder all the socket pins.

Referring to the component locations shown in Figure 2 (Part 1, Apr. '03), install the resistors. Install the trimmer potentiometers and solder. When you bend the leads on the 1N914 diode, hold the lead with your needle-nose pliers, grabbing the lead between the glass package and the bending place. That way you won't crack the glass. But you have to hold really close to the case because the diode goes in on 0.3" centers.

Yes, the diode is polarized — match the banded end with Figure 2 (Part 1, Apr. '03). The banded end is the cathode, and it must look into the positive side of polarized capacitor C1. The pattern of this assembly procedure is pretty simple: we install low-profile stuff first.

When you install the polarized capacitors C1 and C2 you will, of course, take care to orient them properly as indicated by the "+" mark on Figure 2 (Part 1, Apr. '03). The electret microphone is also a polarized part like the electrolytic capacitors, but it isn't usually marked as well, so look it over carefully. The lead that is attached to the case of the microphone is the negative lead. That lead attaches to the ground side of your circuit. The light-emitting diode (LED) also is a polarized part. Its cathode is marked by the flat portion of the plastic case, so use the orientation shown in the component placement drawing.

The 0.1 microFarad capacitors C3 and C4 are not polarized — they can go in either way. The 78L05 voltage regulator must be oriented with its flat face toward the center of the printed circuit board, as shown.

At this point it would be a good idea to look your work over carefully. Measure the resistance from the ground side (GND) of the circuit to the pad marked DTR. If you have a small resistance, or no resistance, then there is almost certainly a solder-bridge somewhere.

If things look okay, install the LM324 op-amp following the orientation indicated in the component placement drawing. Pin 1 is toward the center of the board.

Make a three-conductor serial cable. If your computer has a nine-pin connector on the serial port, then on a nine-pin DB9S (sockets) connector, DCD is on pin 1, DTR is on pin 4, and GND is on pin 5. If your PC serial port has a 25-pin connector, then you need a DB25S (sockets) connector, and DCD is on pin 8, DTR is on pin 20, and GND is on pin 7. Connect the opposite ends of these conductors to your circuit board at the corresponding pads marked DCD, DTR, and GND on the component placement drawing.

Make a two-conductor patch cord for connecting audio input from your radio.

At the circuit board solder, the patch cord leads to the pads marked Radio IN and GND. The other ends most likely will need a miniature phone plug to connect to the earphone jack on your radio.

Connect the tip to radio IN and the ring to GND. **Caution:** If your radio is powered by the 110-volt AC line, make sure your radio audio output jack is isolated from the AC line. Use your ohmmeter to check continuity from both sides of the audio output jack to the prongs on the radio AC power cord. If you find *any* continuity, that is, any low resistance, do *not* use that rinky-dink radio.

Use a battery-powered radio, or find a radio with properly transformer-isolated power supply.

"ALICE100" in this case. The program also obtains from the preamble the pointer — one in this case — to the start of the keys used. Starting in the padfile ALICE100 at that location — sequentially using one key for each cipher character in the ciphertext — the program decrypts the message and displays the result. The session looks like this:

```
getmsg
qbasic /run msgin
name of the MESSAGE file to decrypt: tobob1
kc% = 1

alice100: 11-07-2002 16:36:59
Mother Hubbard says
the cupboard is bare.

message contains  43 characters
```

You should now erase the padfile named ALICE100 and then rename PAGETEMP to ALICE100

The line kc% = 1 displays the pointer, obtained from the message header, to the start of the key characters used.

Update the Padfile

After the msgin.bas program has decrypted the message, it will write back to the disk all the remaining unused keys from the padfile. The program writes these keys to a temporary file named PAGETEMP. After the program exits back to the shell, Bob should do what the program suggests — erase the padfile that was used (ALICE100 in this example) and then give that name to the temporary file, with the command

```
rename pagetemp alice100
```

This, of course, is exactly the same as Alice will have done after she checked the message, just before sending it. It is important that both Bob and Alice update the padfile after it has been used, because all used keys should be destroyed. Although the padfiles are thus consumed, any padfile can be used until it no longer contains enough keys to encrypt a message.

Keep Disks Full

Alice and Bob will, of course, store their floppy disks where Eve cannot can gain access to them. Yet in anticipation of the possibility that a disk may fall into the wrong hands, there is another security measure that should be followed — keep the floppy disks full. After using a disk, and before storing it away, use the command

```
makepad
```

and give the anrng.bas program a basename, such as "PAD," and a large file count. The padfiles created are not intended to be used. Their purpose is simply to overwrite any erased files on the disk. That way, an eavesdropper who gains access to the disk — even one who may possess sufficient low cunning to retrieve erased information without cooperation of the file system — will discover no keys with which to decrypt old messages, such as Eve may have intercepted and saved. There will be unused keys on the disk, but all the used keys will have vanished.

Protocol Eliminates Bookkeeping

When he receives an encrypted message from Alice, Bob doesn't have to know what pagefile Alice used to encrypt the message. The message header tells the one-time program the name of the pagefile that was used to encrypt the message. Since Bob always uses one of his own set of padfiles to encrypt a message that he sends to Alice, and Alice, for her part, always encrypts a message with one of her own set of padfiles, the keys that Bob needs for decrypting a message from Alice are always available on Bob's padfile disk. On Alice's copy of that padfile, those keys will have been erased after Alice sent the message to Bob. On Bob's copy of that padfile, those keys will be erased after Bob decrypts Alice's message. In other words, while Alice and Bob follow this protocol, after a transmitted message has been decrypted, all the key characters used for that message will have been destroyed.

Summary

Unpredictable, non-reproducible, sequences of secret, real random numbers, kept secret, with each number used just one time and then destroyed, can be used to create encryptions that may be unbreakable. Atmospheric noise appears to be a usable source of such real random numbers.

Installation of one-time pad type encryption requires close cooperation on the part of users. Once the system has been set up and the padfiles have been created and are in the hands of the users, keeping those files secret, and assuring that used keys are destroyed, are the primary maintenance requirements. While the padfiles remain secret, one-time pad type encryption offers inviolable privacy. **NV**

Resources

The single-sided printed circuit board can be ordered for $9.50 postpaid from Micromethods, P.O. Box 909, Warrenton, OR 97146.

QBASIC is included with all recent versions of DOS. Windows95 users should be able to find their copy of QBASIC on the Windows CD in the \OTHER\OLDMSDOS directory.

Source code for all the programs in this article can be automatically unpacked from the file onetime.bas that can be downloaded from **www.seasurf.com/~jdennon.** If you are a DOS user migrating over to Linux, then on that page do check out my pretty good editor for GNU/Linux, presented in the book *Build Your Own LINUX C Toolbox.*

Gregory J. Chaitin's paper on "Randomness and Mathematical Proof" can be found at **www.cs.auckland.ac.nz/CDMTCS/chaitin**. David Eastlake's RFC 1750 on "Randomness Recommendations for Security" is available at **www.cis.ohio-state.edu/cgi-bin/rfc/rfc1750.html**. Random numbers from atmospheric noise can be downloaded from **www.random.org.**

Random numbers from radio-active decay can be downloaded from **www.fourmilab.ch.** For background on cryptography in practice, written by a professional in the field; with discussion of the one-time pad and many other schemes, find a copy of Bruce Schneier's *Applied Cryptography*, published by Wiley. The second edition is available at Amazon.

Build an RC Motor Tachometer

Record a motor's speed while in use, and save the info for later analysis.

Fast electric boating is becoming increasingly popular due to advancing technology. New battery and motor designs push these electric water rockets to incredible performance levels. Even though the electric boater has faster and more efficient gear at his or her disposal, power is limited when compared to combustion-propelled craft. If a racer hopes to be competitive, it is important to be very meticulous with equipment choice and set-up.

There are numerous factors that dictate a model's performance on the water: prop type, prop angle, hull type, motor type, etc. Knowing the motor's speed during testing of a particular set-up can provide useful information in the quest for optimum performance.

This article describes a project that will record the motor's speed while in use, and save the information for later analysis. The unit is installed in the model during the testing sessions. When each session is complete, the data is retrieved via the unit's serial port. Data will be displayed in the form of motor revolutions-per-minute. The device is typically removed when a satisfactory set-up has been found.

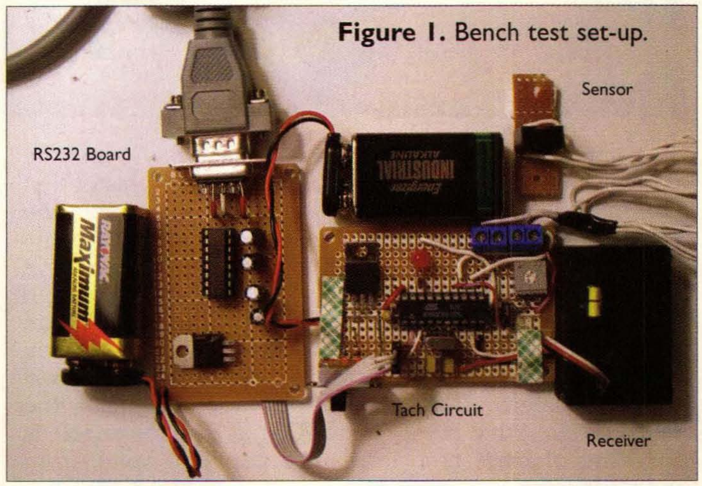


Figure 1. Bench test set-up.

CIRCUIT DESCRIPTION

The heart of the RC-boat tachometer is an Atmel 2313 microcontroller running at 10 MHz (Figure 1). I used Bascom-Avr software from MCS Electronics to program the tiny 20-pin device. Bascom-Avr is an easy-to-use BASIC compiler that is very powerful and inexpensive. The STK500 development board from Atmel was used for development/programming.

The circuit was built using point-to-point wiring. The low parts count and non-critical parts placement justified the use of a perf-board assembly method. If hard wiring is not preferred, MCS Electronics offers an assembled 2313 controller board that would simplify the building process.

Its own nine-volt battery powers the unit. If the motor or receiver battery was used, noise could be introduced into the tach circuit causing the controller to reset. A five-volt regulator does the job of providing the proper TTL voltage level. The resistor R1 and capacitor C1 hold the controllers reset input low for a short time after powering up the unit until C1 is charged. The charge delay prevents the controller from executing code until VCC is stable.

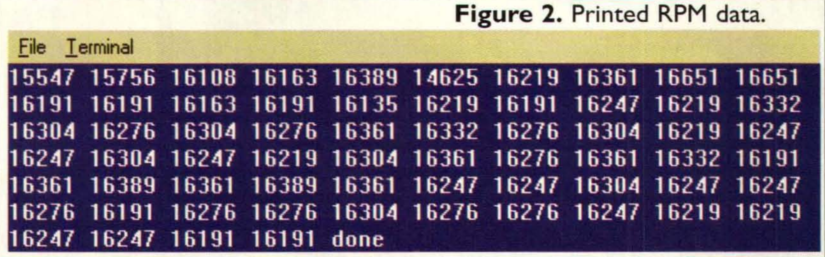
The motor speed information is measured using a slotted optical sensor that contains an infrared diode and a light dependent transistor separated by a small gap. A plastic disk with a small section notched-out is connected to the motor shaft, and the sensor is mounted in a way that the disk will spin freely in the gap separating the diode and transistor (see Figure 3). Each motor rotation is detected when the notch passes through the sensor letting the infrared beam strike the phototransistor. The sensor's transistor will turn on causing pin 12 of the controller to go low. The sensor signal is connected to the controller's + input of the on-board comparator. R4 provides the - input of the comparator. When the + input goes below the - input, an interrupt will occur that performs measurement/data-logging duties.

The use of a three-channel radio-controlled system allows for two channels to control the craft, while the third channel performs the data-collection triggering. The user will start the data collection, typically, during a high-speed straight run. The motor speed is sampled every half-second for 32 seconds. Sixty-four samples provide enough information for accurate performance measuring. The motor should be at maximum speed during the collection to obtain useful information. The range of the tachometer is 800-50,000 RPM. J3 is used to start the data collection dump after a successful test session. If the jumper is on J3 after power-up, the unit will read the data from the EEPROM and send it out of the serial port. LED1 provides a visual indicator of the unit's condition.

SOFTWARE THEORY

After power-up, the usual peripheral configuration, variable initialization, and interrupt handling takes place.

Figure 2. Printed RPM data.



File Terminal

15547	15756	16108	16163	16389	14625	16219	16361	16651	16651
16191	16191	16163	16191	16135	16219	16191	16247	16219	16332
16304	16276	16304	16276	16361	16332	16276	16304	16219	16247
16247	16304	16247	16219	16304	16361	16276	16361	16332	16191
16361	16389	16361	16389	16361	16247	16247	16304	16247	16247
16276	16191	16276	16276	16304	16276	16276	16247	16219	16219
16247	16247	16191	16191	done					

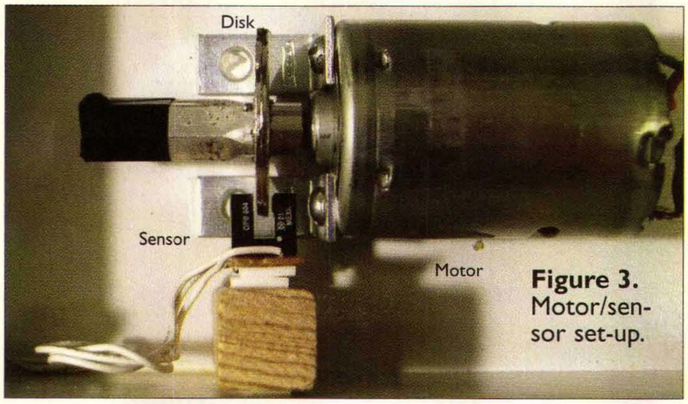
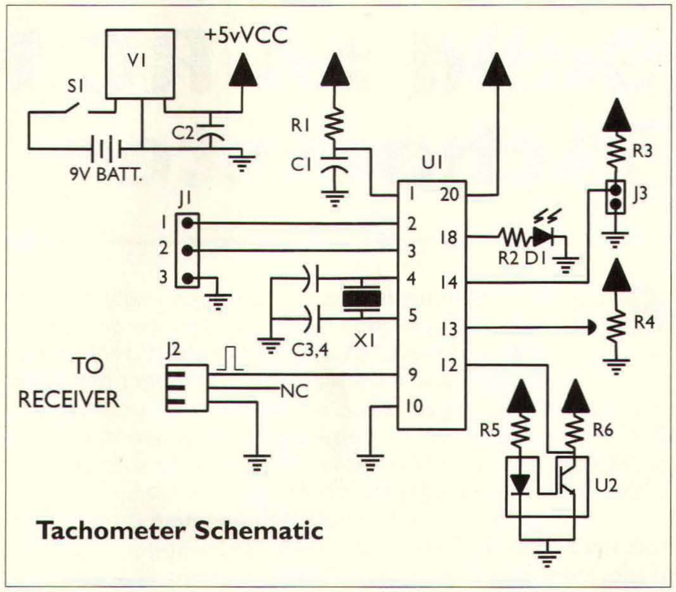


Figure 3. Motor/sensor set-up.



Tachometer Schematic

Two noteworthy initializations are the variable M and the comparator. Acsr.7 and Ascr.2 are bits in the register that control the on-board comparator. These bits enable the comparator and connect the comparator output to the input capture of timer1. The comparator is used to receive the output from the optical sensor. The transistor output from the sensor is not always perfect. The "OFF" state may provide a slightly low logic 1, and the "ON" state may provide a slightly above zero level. The comparator will trigger an interrupt when the sensor input falls below the negative input that is set by the 20k pot. The M variable is the time of each timer1 tic. The captured value from timer1 is the time of one motor revolution.

The first task that the processor must perform is to check if J3 has a jumper installed. The presence of a jumper will cause a gosub to "sub_print." The "sub_print" routine will read the first memory location of the internal EEPROM and store it in variable A.

The total time for one revolution is then calculated and stored in variable K. Next, the number of revolutions in one second is calculated and stored in variable L. After finding out the number of revolutions in one second, multiplying L by 60 will give revolutions per minute (RPM). The RPM data is converted to a non-decimal number by setting variable W equal to variable K that now holds the RPM data in decimal form. This is a handy feature when it is necessary to change data types. The final part is to print the data to the serial port. This process will continue until every location of the EEPROM has been read and printed. LED1 will blink indicating a successful print.

If a jumper is not present at J3, the processor will light LED1 and perform pulse-width measurements on the signal received on pin 9 from the system's receiver. The GET-PULSE routine is used for measurement duties by simply incrementing the variable V while the receiver signal is HIGH. I have found the variable V count to be 736 while the third channel was not activated. I settled on a value of 850 to trigger the data collection. When the third channel is activated, the signal's pulse-width measurement will climb above 850.

The builder should experiment with the radio that will be used for the project. My radio's third channel uses a button for activation that has a position adjustment. The adjustment controls what the pulse width is during activation. Some radios use a fixed position.

I wrote a small program using partial code from this

PARTS LIST

- U1 — Atmel 2313-10 microcontroller
- U2 — Slotted optical sensor
- V1 — +5VDC regulator
- X1 — 10 MHz crystal
- R1, R6, R3 — 10K ohm resistor
- R2 — 330 ohm resistor
- R4 — 20K ohm pot
- R5 — 110 ohm resistor
- D1 — Red LED
- J1, J3 — Single row header
- J2 — RC servo connector
- C1, C2 — 1 uF capacitor
- C3, C4 — 22 pF capacitor
- S1 — Micro SPST switch

The usage is what raises this projects skill level rating. To use the tachometer as described here, the builder must have model building and piloting experience. Every model is different which requires its own special installation requirements. Mounting the sensor-disk to the motor shaft is the most challenging part requiring some ingenuity to be inexpensive. A custom machined motor coupler/hub for disk mounting would be perfect, but expensive. The author can be reached at: **atrueland@mybluelight.com**.

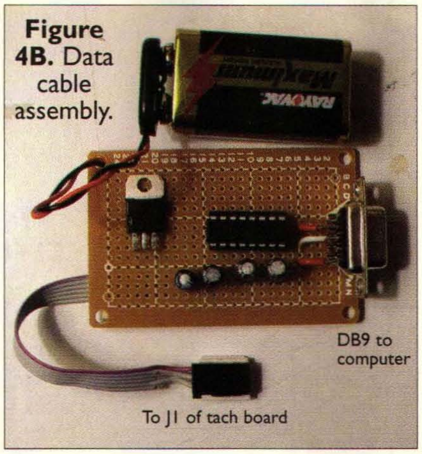


Figure 4B. Data cable assembly.

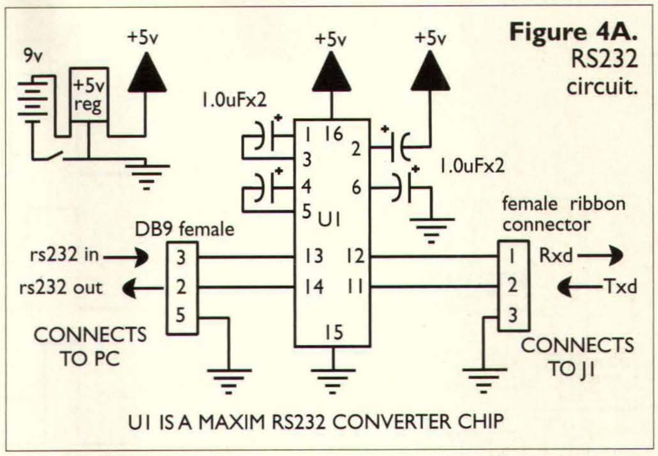


Figure 4A. RS232 circuit.

project that measured the signal's pulse width, and printed the variable V count. Figure 6 shows what the control signal looks like. Knowing what the measurement is before and during channel activation will determine what value should be used as a trigger point. The program constant 850 may need to be changed for different systems.

The program will continue by enabling the interrupts and entering a service loop. LED1 will go out while in the loop, providing a visual indicator that the data collection is ready to begin. The loop provides a place for the processor to wait for an interrupt to occur. When the notch on the plastic disk passes through the sensor slot, the "Isr_cap1" routine is called upon. This routine performs the motor speed measurement and stores it in the EEPROM. During the first sensor trigger, the timer is cleared and variable B is set to one. This is a flag indicating the start of the revolution measurement. Upon completion of the revolution, the "Isr_cap1" routine will be called again. Now that variable B is set to one before entering the routine, timer1 capture data is stored in the EEPROM. The stored value represents the number of timer1 tics that occurred during one revolution. Finally, variable B is cleared, the EEPROM pointer incremented, and a small delay is performed. This process is repeated until the EEPROM is full. After the EEPROM is full, LED1 will blink indicating a successful data collection.

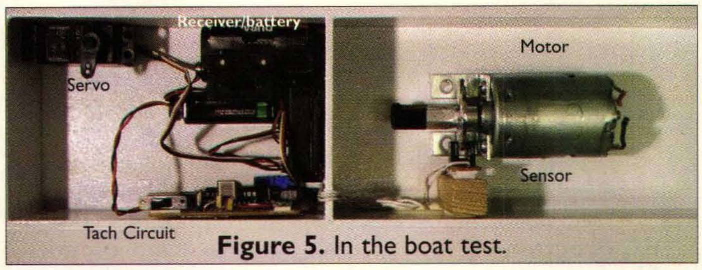


Figure 5. In the boat test.

USING THE TACHOMETER

The circuit board, battery, and sensor need to be installed in the boat securely to prevent vibration from causing a failure. Figure 5 shows a typical installation. Unfortunately, during the testing of the tachometer, my boat hit a log and sank into the dark water. This was a real bummer because replacement will take some time due to an empty boating budget. I had three successful runs that provided great results before the accident. I was having so much fun that I forgot to take pictures of the ready-to-run installation in the boat.

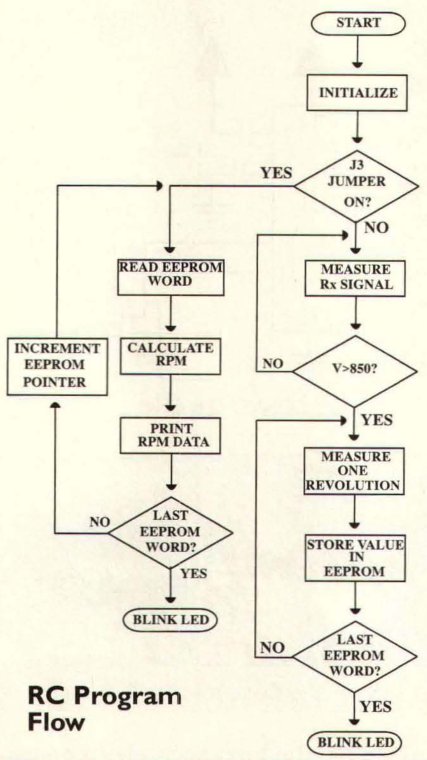
The hull I used to test the tachometer was a wooden catamaran built from scratch. A simple tie wrap and stick-

Digi-Key (**www.digikey.com**)
Components
AVR development board

MCS Electronics (**mcselec.com**)
BASCOM-AVR software
Development boards

Atmel (**www.atmel.com**)
Microcontroller docs

Tower Hobbies
(**www.towerhobbies.com**)
Radio control equipment



RC Program Flow

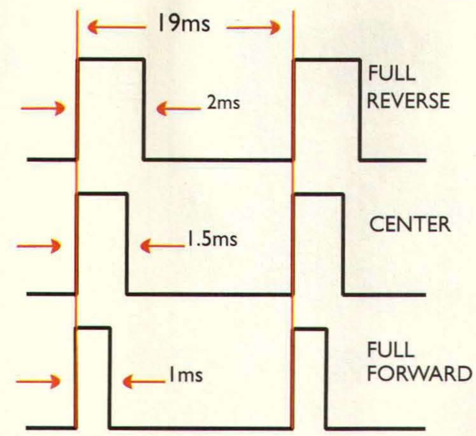


Figure 6. Receiver control signal.

on holder provided a satisfactory mount for the controller board.

Wrapping the controller board in foam provides some vibration protection.

The plastic disk must be mounted to the shaft of the motor, and the sensor mounted so that the disk spins freely in the sensor's slot. Figure 3 is the bench test set-up that shows the disk inside the sensor. The battery can be secured using VELCRO® tape. The servo cable with J2 needs to be plugged into the third channel of the receiver. This provides the trigger for the data collection to start. The jumper on J3 must be absent for data collection to occur.

Once the unit is installed and the boat has been prepped for running, it's time to do some laps. The transmitter is first turned on, followed by the receiver. The tachometer is last to be powered-up. If the transmitter is turned on last, the tachometer could start to record data. LED1 will light in five seconds after being energized indicating a ready status. The delay is used to allow time for the transmitter to be turned on if the transmitter is powered before it. A test to verify that the third channel is doing the job of starting the collection should be done at this point. Activating the third channel should cause LED1 to go out; this indicates that the data collection has started. The tachometer needs to be reset by a power-cycle before launching the model. After the boat is on a steady course, activating the third channel will start the data collection. After about 35 seconds, collection will stop. Upon retrieval of the boat, LED1 on the tachometer should be blinking, indicating a successful collection.

The next step is to view the data that was recorded. The unit must be turned off and J3 installed. The tachometer does not have an on-board RS232 converter in an effort to save power and space. The fabrication of a data cable is needed to transfer data to a device that uses RS232 (see Figure 4A). One end of the data cable must be connected to J1, and the other end connected to a device capable of displaying the serial data (see Figure 4B). I chose to use a laptop computer running a terminal emulator. With J3 installed, the data will transmit upon turning on the tachometer. Figure 2 shows the data as it appears after the data print. LED1 will blink at the end of the data dump.

FINAL THOUGHTS

Mounting the plastic disk to the motor shaft requires some ingenuity. My typical method was a press fit to the shaft. Press fit works fine for smaller motors, but large motors will need something more substantial. Mounting the disk will prove to be the most challenging part of the project.

A whole article can be written about RC control systems. This project was designed around a system that uses pulse-width control signals. Digital and PPM systems have different control signals that would need to be handled differently. It is important to be very familiar with the system to be used. If direct interfacing to the radio's signal is not desirable, a micro-servo connected to the third channel could be used. The servo could close a switch connected to an input of the controller. The tachometer circuit can be easily modified to suit different needs. If a larger data sample is needed, a microcontroller with more EEPROM storage could be used.

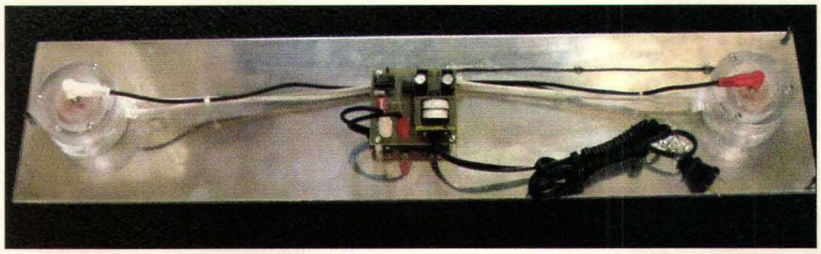
Boaters that use a two-channel radio to control their craft will require a modification for triggering the data collection. One method would be to remove the pulse-measuring code, and change the half-second delay to a full second. This modification will allow the data collection to start as soon as the boat begins to move. The collection will last about one minute. It takes little time for a typical RC boat to reach full speed, leaving plenty of high-speed measurements.

The circuit is not limited to RC boats. RC cars could also benefit from this project. One particular type would be a RC drag racing car. Measuring wheel speed during its three-second run would help to monitor performance. The tachometer can also be used on fuel burning models. The excessive vibration from combustion engines will require sturdy installation methods. Having only 60 samples to view, using a terminal emulator is sufficient. If larger samples are collected using bigger controllers, a program that graphs data from the serial port could be useful. Searching the Internet could yield a freeware program that processes serial data for analysis.

All the parts for the project can be obtained from Digi-Key (**www.digikey.com**). The STK500 development board can also be obtained from Digi-Key. The programming software (Bascom-Avr) can be found at **www.mcslec.com**. MCS Electronics provides a fully functional demo version (limited to 2K of code) that would be sufficient for this project. The service and products from MCS Electronics are tops. The result of a project from one hobby that increased the enjoyment of another hobby, proved to be rewarding. You can never have enough information when performance is a must — especially knowing where the logs are. **NV**

Measure Earth Tides with a Tiltometer

See if the world is on the level with this tiltometer/seismograph combo unit.



Everyone knows about the tides of the ocean — how they rise and fall — but what about the tides of mother earth? Most people don't think about how the ocean tides are generated. If asked, the reply is that the moon is pulling on the water. Not quite!

The earth has a crust, mantle, and a liquid core, where the gravitational pull has the most effect. The earth is being squeezed like a grapefruit, which causes the deformation of the earth's crust. The ocean tides are caused by this deformation. One side of the earth is bulging while the opposite side is indenting. The earth, at the equator, moves about ±1 meter every 12 hours. The alignment of the sun with the moon causes different tides throughout the year. Figure 1 shows the earth tides for a period of 16 days. A number of investigators have suggested that the surface of the earth may tilt slightly along a fault line, somewhat in advance of a seismic event.

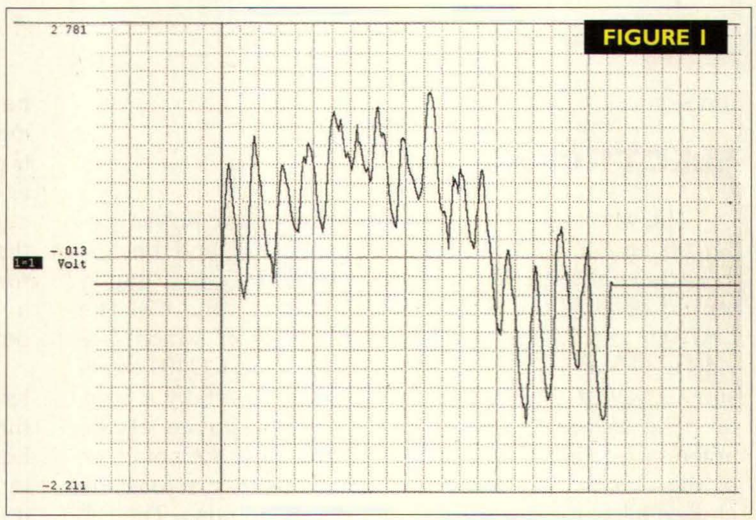


FIGURE 1

The tiltometer presented here is a revised model, which was published in *Scientific American* over 40 years ago. It is capable of detecting .002 seconds of arc, which is about the angle that would be subtended by a dime at a distance of 200 miles. Not only does it detect tilt, but it has the added advantage of being an inexpensive seismometer. Figure 2 shows the 6.8 El Salvador earthquake. I was able to measure the ringing of the earth for 10.5 hours. The top graph is a regular seismograph and the lower graph is the tiltometer.

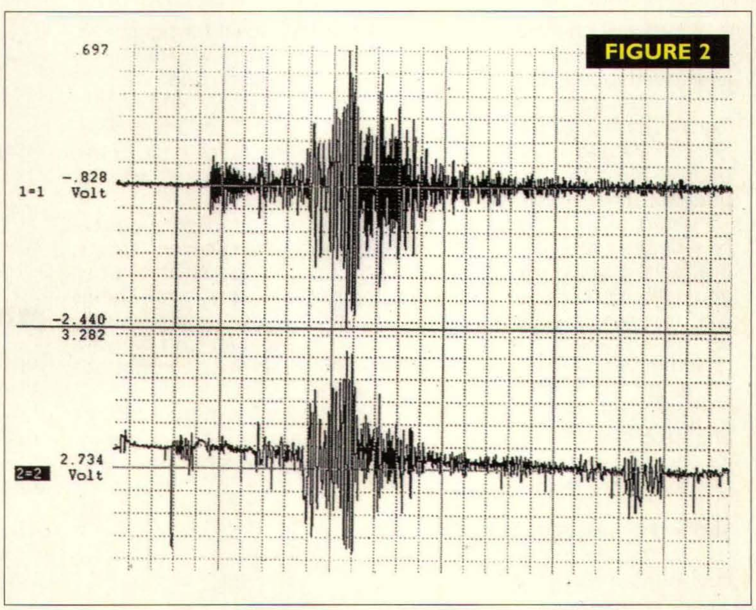


FIGURE 2

The original tiltometer was designed using the displacement of mercury between two, two-inch cups placed 24 inches apart. Mercury has been in the news regarding its potential to cause health problems. Proposals are up for its elimination from oral thermometers, as most people throw their broken thermometers in the trash. Keeping mercury out of the land fills and the ocean has high priority. Scientists are aware of the problems of mercury and, unfortunately, there is no substitute for many scientific instruments due to its density. If handled correctly, and if spills are properly taken care of, it can be safe to use.

Like water, mercury seeks its own level. The height of the mercury is determined by injecting a 4MHz signal into the mercury, making it the transmitting antenna. Two receiving antennas placed just above the mercury determine its height via signal strength. The AC signal is rectified and an instrumentation amplifier is used to amplify the differences in

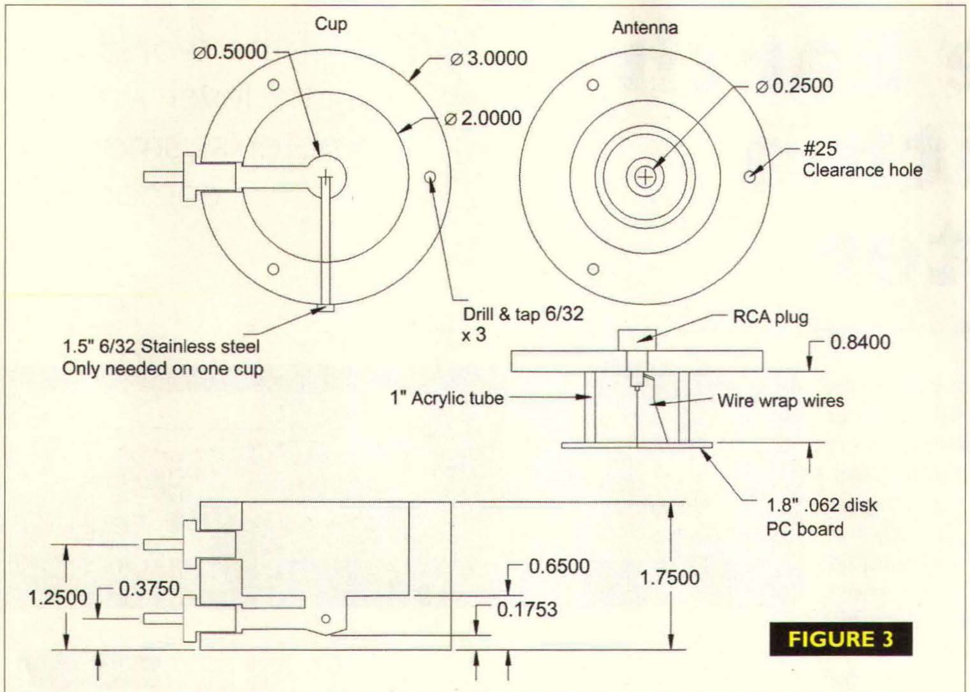


FIGURE 3

the signals.

ELECTRONICS

The whole detection system, including the power supply, fits on a 3" x 3" single-sided circuit board, and the cost in parts is about $35.00. When constructing, it is important to observe the proper polarities of C1 and C2. The LM7815 and LM7915 are voltage regulators which provide a +15 and -15 volts, respectively. The CD4011 is a simple way of generating a 4MHz signal driven by a crystal. The choke resonates with the capacitance of the antenna, and is rectified by D1 and D2. Note the polarities of the two diodes. The trimming capacitors across the chokes allow for maximum tuning of the circuits. The DC voltage generated by the diodes is injected into the instrumentation amplifier. This amplifier has a very high input impedance and a common mode rejection of 106 dB. It is capable of 1-1 amplification to 10,000 amplification by the changing of one resistor. A DIP switch was added to provide amplifications of 1-1, 1-10, 1-100, 1-500, 1-1,000. The output from this op-amp measured from the ground can be recorded by a chart graph or other software. Two RCA jacks are placed on the board and their center terminals are soldered to the board. Solder one 1.5-foot wire to the output of the CD4011. This wire will be connected later.

TILTOMETER

Although the two cups can be machined on a drill press, a lathe makes the machining much easier. Acrylic that is 3" round by 1.75" in height is difficult to find, so I glued two 1" pieces of acrylic together using methyl-chloride, also known as Weld-On four. The cups must be cylindrical and not rectangular to prevent the development of non-linear turbulence. Once you have made the cylinders using the dimensions in Figure 3, drill a 1/2" hole in the center to a depth of .175" from the bottom.

Machine out the cups and polish the inside 2" diameter to a smooth finish. Drill a 1/4" hole from the side through to the center 1/2" hole on the bottom. Drill the bottom hole to a depth of 1/2" with an 11/32" drill, and tap with a 1/8" pipe tap. Drill the top hole with a 11/32" drill and tap. Place the two cups with the pipe threads fac-

MERCURY

Mercury, the messenger for Zeus, was known for his speed. Anyone who has worked with the element mercury will know why it is called quick silver and named after this Greek god.

In the book *Alice's Adventures in Wonderland*, Lewis Carroll had a character called the Mad Hatter. In the 1800s, Mercury nitrate was used in the manufacturing of felt hats. These people, through constant exposure, developed strange behavior patterns. Thus, the term "mad as a Hatter."

Most of us do not realize that we are surrounded by mercury — lighted athletic shoes, old latex paints, fluorescent lamps, old button batteries, fungicides, thermometers, dental amalgams, thermostats, and silent light switches are just a few things with mercury in them. Mercury is odorless, but due to its vapor pressure, is easily absorbed in the lungs. Mercury can cause a rash, but is not easily absorbed through the skin. Its compounds are extremely toxic.

Unfortunately, I have found no substitute for mercury in the tiltometer project. Its conductive powers, and most importantly, its viscosity and density, all play a part in the physics of the oscillation and dampening effects.

HOW TO HANDLE MERCURY

1. Remove all jewelry and wear rubber gloves if you have cuts or abrasions.
2. Place the tiltometer in a cardboard box lined with Saran wrap.
3. Keep the mercury in a plastic bottle with a small opening.
4. Transfer the mercury in a well-ventilated place.
5. Do not allow pregnant woman or children in the area when transferring or if spilled.
6. Transfer over a solid floor without cracks or rugs!

WHAT IF A SPILL OCCURS?

1. Use a syringe, eye dropper, or a sheet of paper to clean up. Adhesive tape can also help to pick it up. *Do not use a vacuum cleaner!*
2. Transfer it to a plastic bottle for disposal. Label it "dirty mercury."
3. Dispose of the mercury at a waste disposable plant or recycle it by cleaning it. (Another subject)
4. *Do not pour it down the sink or dispose in the yard!* The biggest concern is that it will get into the lakes and rivers and form methylmercury via bacterial action which fish absorb and cause the majority of mercury poisoning in man.

No special skill requirements on the electronics. The machining can be done on a drill press, however, it would be best to have the use of a lathe.

ing each other. Using a #29 drill, drill through to the 1/2" hole at right angles to the pipe threads on the left cup. Tap this hole for a #8 6/32 stainless steel screw 1.5" in length. Three holes are drilled and tapped for 6/32 screws on the top of each cup. Two holes for 6/32 screws will be needed on the bottom of each of the cups for mounting, depending on the type of chassis.

ANTENNAS

Two 1/4" pieces of acrylic for the top are turned to match the cups, and three clearance holes are drilled for the 6/32" screws. A 1/4" hole is drilled in the center of each lid. Two 1" acrylic tubes are cut at a length of .8" and glued to the center of the lid.

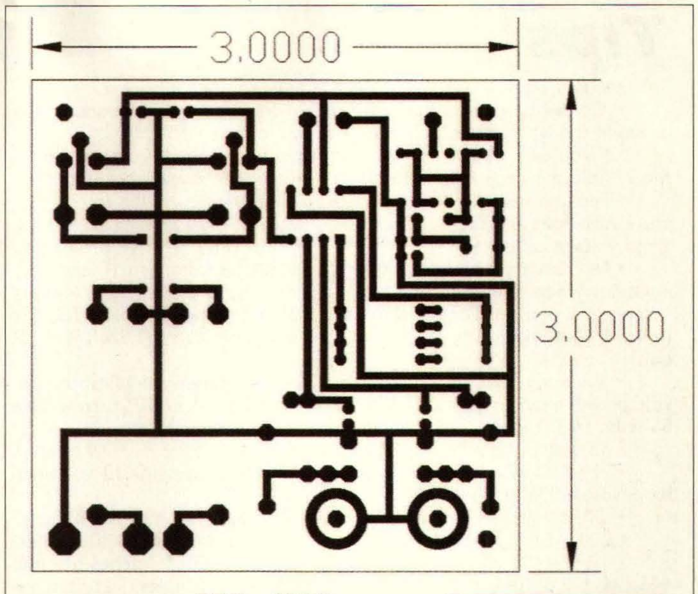
Two double-sided .062 circuit boards, 1.8" round, are turned and a small hole is drilled using a #60 or PC drill in the center. Using an 1/8" drill, remove about 1/16" of the copper from one side of the disks (top). Push a 2" small wire (wire wrap works well) from the top side and solder it to the bottom. Solder another wire to the top side within 1/4" of the center hole. This forms a capacitor out of the circuit board. Sandpaper the excess solder off the bottom side so that the circuit board is flat. If carefully done, the wire will still be soldered to the inside of the small hole.

Place a shielded RCA jack through the lid and solder the wire coming from the bottom of the disk to the center terminal. The top wire is soldered to the ground terminal. Center the disk and superglue to the acrylic tube, pushing the excess wire into the acrylic tube. Coat both sides of the copper with clear acrylic or fingernail polish to prevent corrosion.

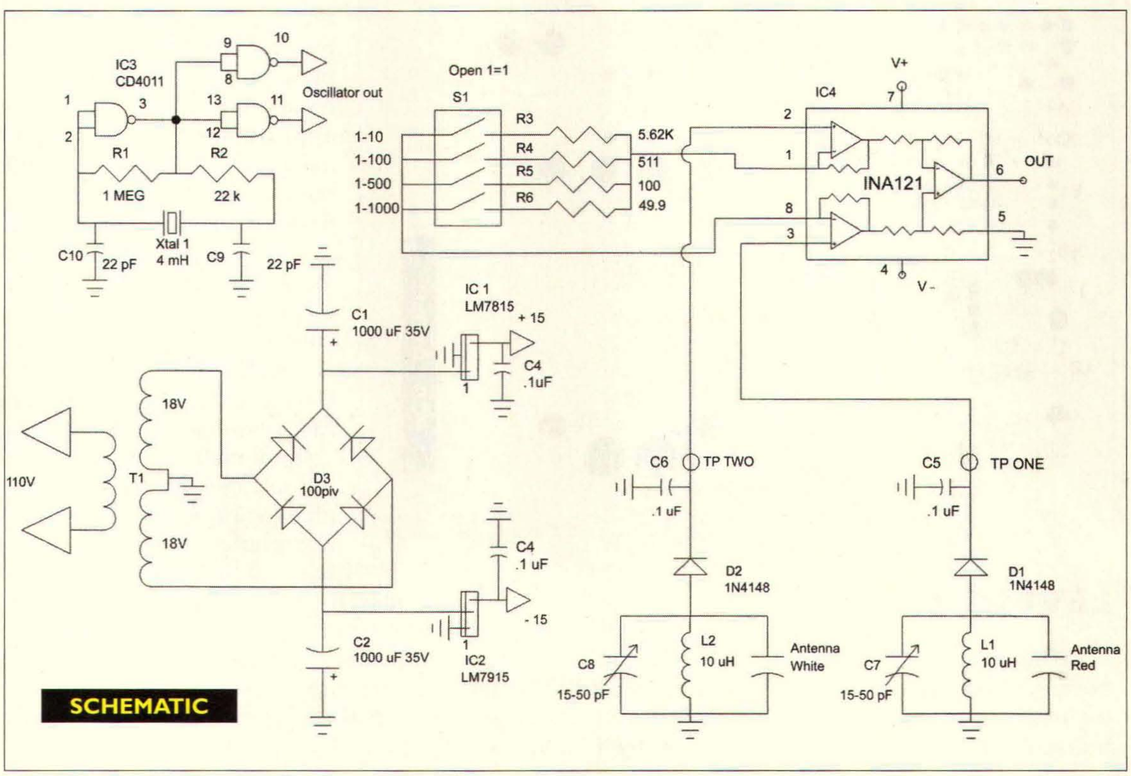
FINAL ASSEMBLY

Mount the cups at 24" centers. The circuit board should be mounted between the cups using 3/4" metal standoffs (for grounding the board to the chassis). I have used 1/2" aluminum U channel, but prefer 1/4" 39"L x 6"W plate aluminum. Do not use wood, as it will change due to humidity. Two 8/32 screws are placed at one end of one side and one 8/32 screw is placed in the center at the other end for leveling. I used three acorn nuts on the bottom of the screws to prevent the bottom thread from walking the unit when being adjusted. For more tips see the sidebar.

You will need four 1/8" pipe to 3/32" tubing adapters and two pieces of 3/32" ID tubing. Run the tubing under the board. Solder the transmitting wire to a #8 lug and using the 1.5" stainless steel screw, screw into the left cup.



PCB PATTERN



SCHEMATIC

Tips

- When tapping the pipe threads, use water as a lubricant.
- Centering of the antenna can be done easily by mounting the board in the lathe chuck and using a center on the RCA plug.
- If you drill a small hole in one of the lids of the cups just next to the 2" hole, a syringe can deliver extra mercury to tweak the output.
- The unit will take about a day to truly settle down due to temperature variations and the wetting of the plastic. Use the leveling screws for gross voltage offsets and the WinDaq offset for small voltage offsets.
- To calculate the sensitivity, place the amplification on 10 and take a reading when level, and then a reading after turning the center leveling screw a 1/4 of a turn, or 90°. This will raise the mounting board 7.8 mils (mil = 1/1000 of an inch; 1/32 turns = 31.3 mils per turn; 31.3 x 1/4 = 7.8 mils).
- Since you will be using the unit on 100 times amplification, the voltage will need to be multiplied by 10. (E.g., 5.5 volts / 90° turn will be 55 volts / 90° turn.)
- 55 volts / 7.8 mil = 4.3 volts per mil.
- The A/D 12-bit converter is capable of measuring .0012 volts per bit. 5 volts/4096 bits = .0012 volts / bit.
- .0012 volts per bit / 4.3 volts per mil = 2.8 10-4 mils per bit.
- 200 miles x 5,286 feet / mile x 12 inches / foot = 12,686,400 inches.
- 12,684,400 inches / 28.5 inches per mil = 445,136 inches per mil. 445,136 * 2.8 10-4 = 125 mils subtended per 200 miles. Just about a dime's thickness.

About every three years, I found I need to update my office computer. I took one of the older ones and dedicated it to continuous monitoring of seismic activity. It is connected to a UPS.

I set the computer clock to Greenwich time as earthquakes are reported in this time.

Check out **www.earthquake.com** for the location of earthquakes of large magnitude, and the time of arrival to your location. I use the University of Nevada at Reno for local tremors. Check with your local college to see if they have a seismograph.

Instead of using a 8/32 screw on the single leveling end, I bought a $5.00 micrometer and cut off the C and mounted it to the chassis. This gives a very fine control of the leveling.

The difference in the size of tubing affects the oscillation period of the liquid and the damping effect. The liquids act as a pendulum. The mercury has a pendulum swing of 23.7 seconds with a damping of 1.22 if the OD of the tube is 3/32." Different size cups can be used, and different lengths of tubing can also be used for more sensitivity. The formulations are below:

Oscillation period

T = 2 x pi x D1 / (D2 x the square root of(L/(2 X g)))

Where D1 = inside diameter of the cups
D2 = inside diameter of the tubing
L = center to center of cups in feet
g = 32 (gravity) feet per second per second
T = time period in seconds

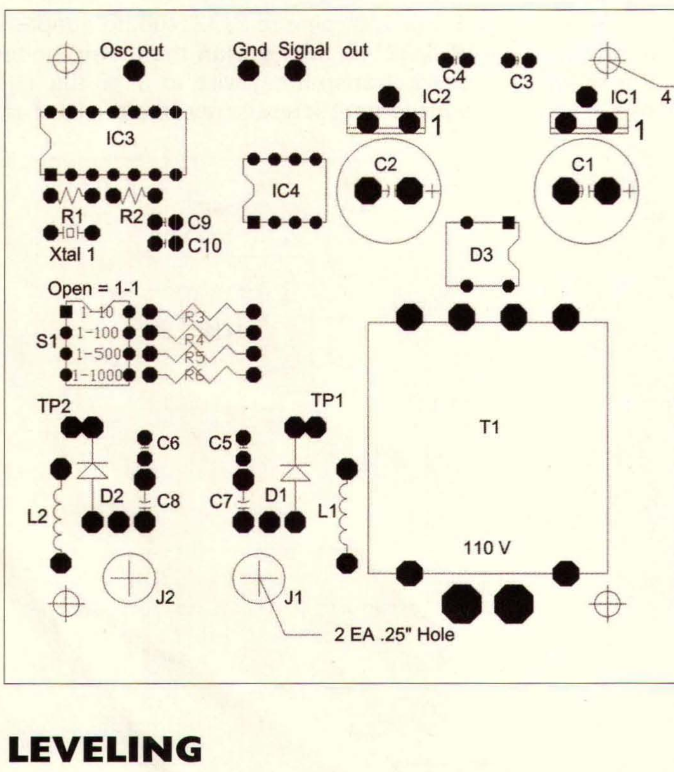
Damping factor

h = 2 x u x T /(d x pi x the square of (D2/2))

Where h = damping factor
u = the viscosity in centi-poise 1 for water 1.5 for mercury
d = density 1 for water 13.55 for mercury
T = time period in seconds
D = diameter of cups in cm

Win-Daq

DI-150RS makes life simple. I collect 720 hours of data to a file. Each day, I run the WinDaq Wave form Browser and look at the file. F7 will allow you to shrink all of the data collected on one page by using maximum compression. Once I have done this, I review for earthquakes. If I have a lot of data, again I use F7 and scan with either a compression of 100 or 1,000. You can print any portion of the data. Check out their web site for further information. **www.dataq.com.** (The DI-150RS is now sold by RadioShack for $99.99.)



PCB LAYOUT

LEVELING

The unit should be placed in an unoccupied area of a basement on concrete. Place in a North to South direction for earth tides, or any other direction if you think your house is tilting. I have mine surrounded by 1" Styrofoam to help with temperature variations and air movement.

Add mercury to the apparatus so that both bottoms are covered evenly. Rock the apparatus to remove any air bubbles. Air bubbles will prevent the mercury from leveling. To check for hidden bubbles, use an ohmmeter and check the conductivity between the cups. Using the leveling screws and a hand level, adjust the level so that the mercury is approximately the same height in both cups (X-axis) and is even on the Y-axis. Remove or add mercury so there is a distance of about 1/16" between the mercury and the antennas.

Connect the RCA cables to the board and to the antennas. Jack 2 should go to the antenna with the single leveling screw. Plug in the unit. Place a DC voltmeter from the Ground Pin to the Test Pin 1. Adjust C3 for a maximum positive voltage. Change the meter to Test Pin 2, and adjust C4 for its maximum voltage. This should be in the range of .5-1 volt on each pin. Place the voltmeter to the op-amp output. Turn off all the DIP switches. Using the single leveling screw, adjust the level so that the output approaches zero volts.

If the voltage is high, turn the screw counter-clockwise. If the voltage is low, turn the screw clockwise. Move switch one (10 amplification) to on and re-adjust. Move switch one off and switch two on (100 amplification), then re-adjust. I use 500 amplification (switch 3). There is 1,000 amplification available (switch 4), but I found that when the sun and moon align, it will peg the chart.

PARTS LIST

		Digi-Key #
C1-C2	1,000uF 35-volt radial electrolytic	P5169-ND
C3-C6	.1 uF 50-volt metallized capacitor	P4525-ND
C7-C8	15-50 pF trimmer capacitor	SG1033-ND
C9-C10	22pF ceramic disk capacitor	P10796-ND
D1-D2	1N4148 diode fast switching	1N4148DICT-ND
D-3	100-volt bridge diode	DF01MIR-ND
IC1	LM7915 Pos 15-volt regulator	NJM79M15FA
IC2	LM7815 Neg 15-volt regulator	NJM78M15FA
IC3	CD4011 NAND gate	296-2031-5-ND
IC4	INA121 FET instrumentation amp	INA121PA-ND
L1-L2	10 uH choke	M7825-ND
R1	1 meg 1/4 watt	1.0MQBK-ND
R2	22k 1/4 watt	22KQBK-ND
R3	5.62k 1% 1/4 watt	5.62KXBK-ND
R4	511 ohm 1% 1/4 watt	511XBK-ND
R5	100 ohm 1% 1/4 watt	100XBK-ND
R6	49.9 ohm 1%	49.9XBK-ND
S1	Four-position DIP switch	CKN1278-ND
T1	110V 18V 1.1 amps split	MT2225-ND
XTAL 1	4 MHz crystal	300-6003-ND
Two-prong power cord		Q100-ND

Digi-Key: www.digikey.com

Miscellaneous

	RadioShack #
Double audio cord	RS43-2650
J1-J4 — RCA jack	RS274-346

Hardware for tiltometer

Mounting
1 ea. 3/8" 6" x 39" aluminum plate
3 ea. 1" 8/32 screws
3 ea. 8/32 acorn nuts
4 ea. 1/2" #6 metal standoffs (board)
4 ea. 3/4" 6/32 screws (board)
4 ea. 1/2" 6/32 screws drill and tap cups to mount
1 ea. 1.5" 8/32

25 mls mercury
Four 1/8" nipple 3/32" adapter, may be obtained from **www.coleparmer.com**

21" 3/32" tubing, may be obtained from **www.coleparmer.com**
1 ea. 1.5" 6/32 stainless steel screw
1 ea. #8 terminal

The board is available for $15.00 + $5.00 shipping. Electronics kit and board (all electronics above) $55.00 + $10.00 shipping. Add $25.00 if you want the board assembled and soldered.

We accept check or money order. Plastic use Pay Pal.
Ron Newton
2230 Damon Rd.
Carson City, NV 89701
775-885-8842
Sjnewt@aol.com

CHARTING

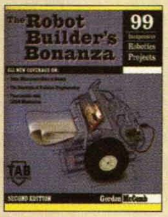
Although a chart recorder works well, you will go through reams of paper. I use a Dataq DL150RS with their 12 bit A/D converter. It is available for $99.99 and records two channels of data allowing for other monitoring to be performed. I have used their eight bit, which sells for $15.00 ($50.00 more if you want to record), but 12 bit is vastly superior. I set it up to record one month of data. Using their WinDaq software, at any time while it is recording, you can view the current data or the file it is writing. If there is a major earthquake, I note the time and the date of occurrence, and WinDaq will perform a time search for that occurrence. You can print out any small portion of the data or the whole month report on one page. It also has the capability of performing Fourier waveform analysis. **NV**

Selected Titles for the Electronics Hobbyist and Technician—

The Nuts & Volts Hobbyist Bookstore

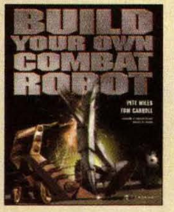
Robotics

The Robot Builder's Bonanza
by Gordon McComb



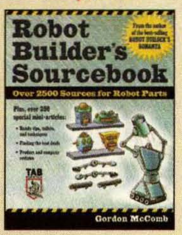
A major revision of the bestselling "bible" of amateur robotics building — packed with the latest in servo motor technology, microcontrolled robots, remote control, Lego Mindstorms Kits, and other commercial kits. **$24.95**

Build Your Own Combat Robot
by Pete Miles / Tom Carrol



Build a powerful and invincible robot for full-blown competition or just for fun using this authoritative robot resource. This team of experts gives you an inside look at the innovative new world of robotic combat, explaining the origins of the sport, as well as all the elements that go into constructing a fighting robot. Learn technical basics from motors and wiring to locomotion, and read builders' true stories from the front lines of robot competition. Whether you're mechanically minded or not, you'll find this book both entertaining and informative. **$24.99**

Robot Builder's Sourcebook
by Gordon McComb *NEW!*



Written by Gordon McComb, author of the classic *Robot Builder's Bonanza*, one of the most popular books ever written on amateur robotics, the Sourcebook lists over 2,500 mail-order suppliers and other sources. You'll find detailed information about the resources, including addresses and phone numbers: In short, everything you need to find – and acquire – common and uncommon robotics parts and supplies. In order to provide a true "robotics goldmine," this one-of-a-kind guide also includes:

- Dozens of informative "sidebars" to help you understand essential robotic technologies such as motor types, sensor design, and how to select the best materials.
- Scores of relevant articles designed to fill-in informational gaps, stimulate thinking, and help you make the most of all the material the Sourcebook makes available to you. **$24.95**

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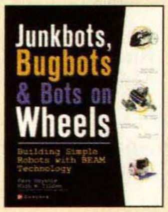
Combat Robots Complete
by Chris Hannold *NEW!*

Here's everything you need to jump into the fascinating and fun world of fighting robots – even if you don't have advanced electronic or engineering skills. The author — a five-year fighting bot and 20-year bot veteran — offers priceless "insider info" covering everything from step-by-step guidance on constructing your first combat robot to the lowdown on the federations that sponsor or guide competitions. **$24.95**

JunkBots, Bugbots, and Bots on Wheels: Building Simple Robots With BEAM Technology *NEW!*
by David Hrynkiw / Mark Tilden



Ever wonder what to do with those discarded items in your junk drawer? Now you can use electronic parts from old Walkmans, spare remote controls, even paper clips to build your very own autonomous robots and gizmos. Get step-by-step instructions from the Junkbot masters for creating simple and fun self-guiding robots safely and easily using common and not-so-common objects from around the house. Using BEAM technology, ordinary tools, salvaged electronic bits, and the occasional dead toy, construct a solar-powered obstacle-avoiding device, a mini-sumo-wrestling robot, a motorized walking robot bug, and more. Grab your screwdriver and join the robot-building revolution! **$24.99**

Building Robot Drive Trains
by Dennis Clark / Michael Owing

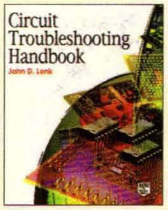
This essential title is just what robotics hobbyists need to build an effective drive train using inexpensive, off-the-shelf parts. Leaving heavy-duty "tech speak" behind, the authors focus on the actual concepts and applications necessary to build – and understand – these critical force-conveying systems. **$24.95**

Everything you need to build your own robot drive train:

* The Basics of Robot Locomotion
* Motor Types: An Overview
* Using DC Motors
* Using RC Servo Motors
* Using Stepper Motors
* Motor Mounting
* Motor Control
* Electronics Interfacing
* Wheels and Treads
* Locomotion for Multipods
* Glossary of Terms/Tables, Formulas

Troubleshooting

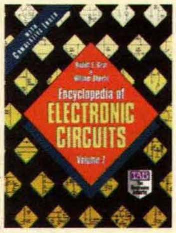
Circuit Troubleshooting Handbook
by John D. Lenk



When it comes to troubleshooting, no other book even comes close — hundreds of circuits are covered in this exhaustive handbook. The result is the most comprehensive and reliable circuit compendium ever assembled.
Heavily illustrated with diagrams and schematics, it uses an easy-to-follow format to help readers understand and troubleshoot a wide range of circuit types, and provides proven circuit testing techniques for all levels of instrumentation. **$39.95**

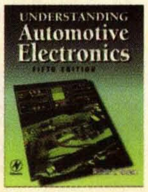
Electronics

Encyclopedia of Electronic Circuits Vol. 7
by Rudy Graf



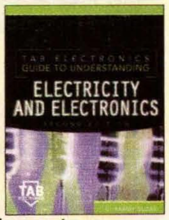
Designed for quick reference and on-the-job use, the Encyclopedia of Electronic Circuits, Volume 7, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. This collection includes the latest designs from industry giants such as Advanced Micro Devices, Motorola, Teledyne, GE, and others, as well as your favorite publications, including *Nuts & Volts*! **$39.95**

Understanding Automotive Electronics *Fifth Edition*
by William B. Ribbens



This edition of Understanding Automotive Electronics covers the most recent technological advances in operation and troubleshooting of electronic systems and components. This is a practical text, suitable for the automotive technician, student, or enthusiast. It includes low-emission standards, on-board diagnostics and communications, digital instrumentation, and digital engine control. **$34.99**

Guide To Understanding Electricity & Electronics
by Randy Slone



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Microcontrollers

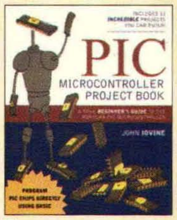
Programming & Customizing the HC11 Microcontroller
by Tom Fox

Applications bazaar for the 68HC11 microcontroller. Squeeze every drop of power out of Motorola's wildly popular family of 68HC11 true 8-bit single chip computers! From basics to complete applications. **$39.95**

Programming & Customizing PICmicro Microcontrollers
2nd Edition by Myke Predko

This book is a fully updated and revised compendium of PIC programming information. Comprehensive coverage of the PICMicro's hardware architecture and software schemes complement the host of experiments and projects making this a true, "learn as you go" tutorial. **$49.95**

PIC Microcontroller Project Book
by John Iovine

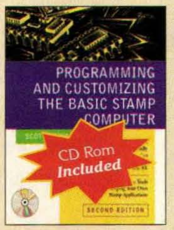


This project-oriented guide gives you 12 complete projects, including: using transistors to control DC and AC motors, DTMF phone number logger and distinct ring detector and router ... home automation using X-10 communications ... digital oscilloscope ... simulations of fuzzy logic and neural networks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

Programming & Customizing the 8051 Microcontroller
by Myke Predko

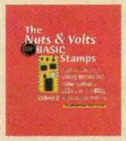
Programming and Customizing the 8051 Microcontroller puts you in control of the 8051's architecture and instruction set — and even supplies a baker's dozen of ready-to-build example applications, programs, and circuits. Best of all, the included CD-ROM supplies source code for the book's experiments and applications. **$39.95**

Programming & Customizing the BASIC Stamp Computer
by Scott Edwards



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

The Nuts & Volts of BASIC Stamps Volumes 1-3



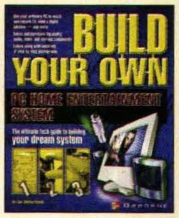
$29.95 each | **$49.95** 2 volumes | **$69.95** all 3 volumes

In 1995, Scott Edwards began authoring a column on BASIC Stamp projects in *Nuts & Volts Magazine*. The column quickly became a favorite of *Nuts & Volts* readers and continues today with Jon Williams at the helm. *The Nuts & Volts of BASIC Stamps* is a three-volume collection of over 90 of these columns.

Volume 3 is new and contains columns 76-92!

Home Entertainment

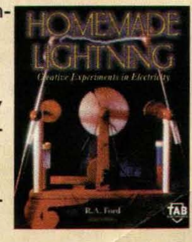
Build Your Own PC Home Entertainment System
by Brian Underdahl *New!*



Learn to use PC DVD drives, DVD recorders, and massive hard drives to create a home entertainment system that's comparable to what you'd enjoy from expensive, individual components. Who needs the movies? Now, you can achieve stunning audio and top quality video results through your PC. This book shows you how to build your own home entertainment center using an ordinary PC. Watch and record TV shows and movies, put your entire CD collection on your hard drive, and listen to radio stations from around the world. **$24.99**

High Voltage

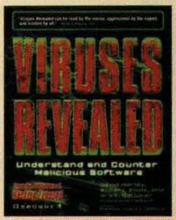
Homemade Lightning: Creative Experiments in Electricity
by R.A. Ford



Enter the wide-open frontier of high-voltage electrostatics with this fascinating, experiment-filled guide. You'll discover how to make your own equipment, how electricity is used in healing, and the workings of many experiments in high potential physics! **$24.95**

Computer Hacking

Viruses Revealed *New!*
by David Harley / Robert Slade
Urs Gattiker



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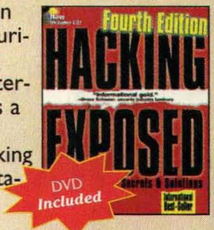

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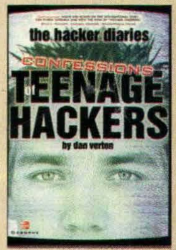

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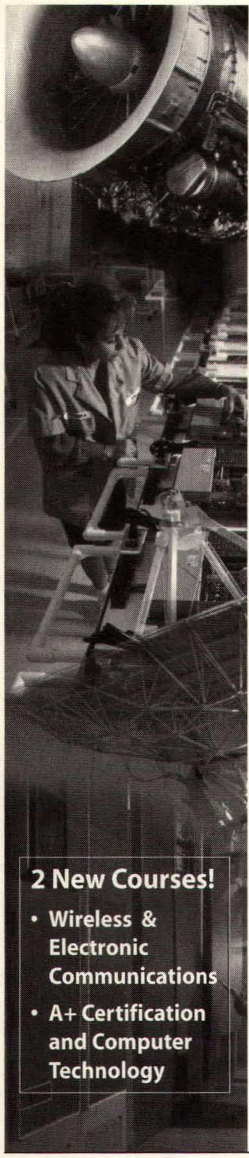

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DEVELOPER-FRIENDLY USB

Take a detailed look at how easily a USB-based device can be developed.

by Don L. Powrie

As the popularity of USB continues to increase, so does the desire and need for easier ways to develop USB-based products. Lots of integrated circuit manufacturers are now offering USB serial engines and integrated USB/microcontroller chips. The use of these devices assumes you will take on the burden of all required software development.

The development of most new USB-based products begins with the laborious and frustrating task of writing a device driver. This task can easily consume the bulk of a developer's free time (nights and weekends, that is) trying to stay on schedule. This task can be simplified somewhat by using the Human Interface Device (HID) class, or it can be eliminated altogether by using FTDI's royalty-free drivers. The only catch with using FTDI's drivers is that they only work with FTDI's chips. FTDI offers two versions of their USB chips (USB to UART and USB to parallel FIFO), as well as two versions of their drivers (Virtual Com Port and DLL).

This article will describe a complete USB-based product design — start to finish — for acquiring temperature data from two digital temperature sensors. The USB-UART version of the FTDI device (FT232BM) will be used, as well as their Virtual Com Port drivers.

MICROCONTROLLER

As mentioned above, FTDI (**www.ftdichip.com**) makes both a parallel and a serial version of their USB chip. Connection to the parallel version (FT245BM) requires eight data lines and four handshaking lines to properly implement the interface. What if you only have

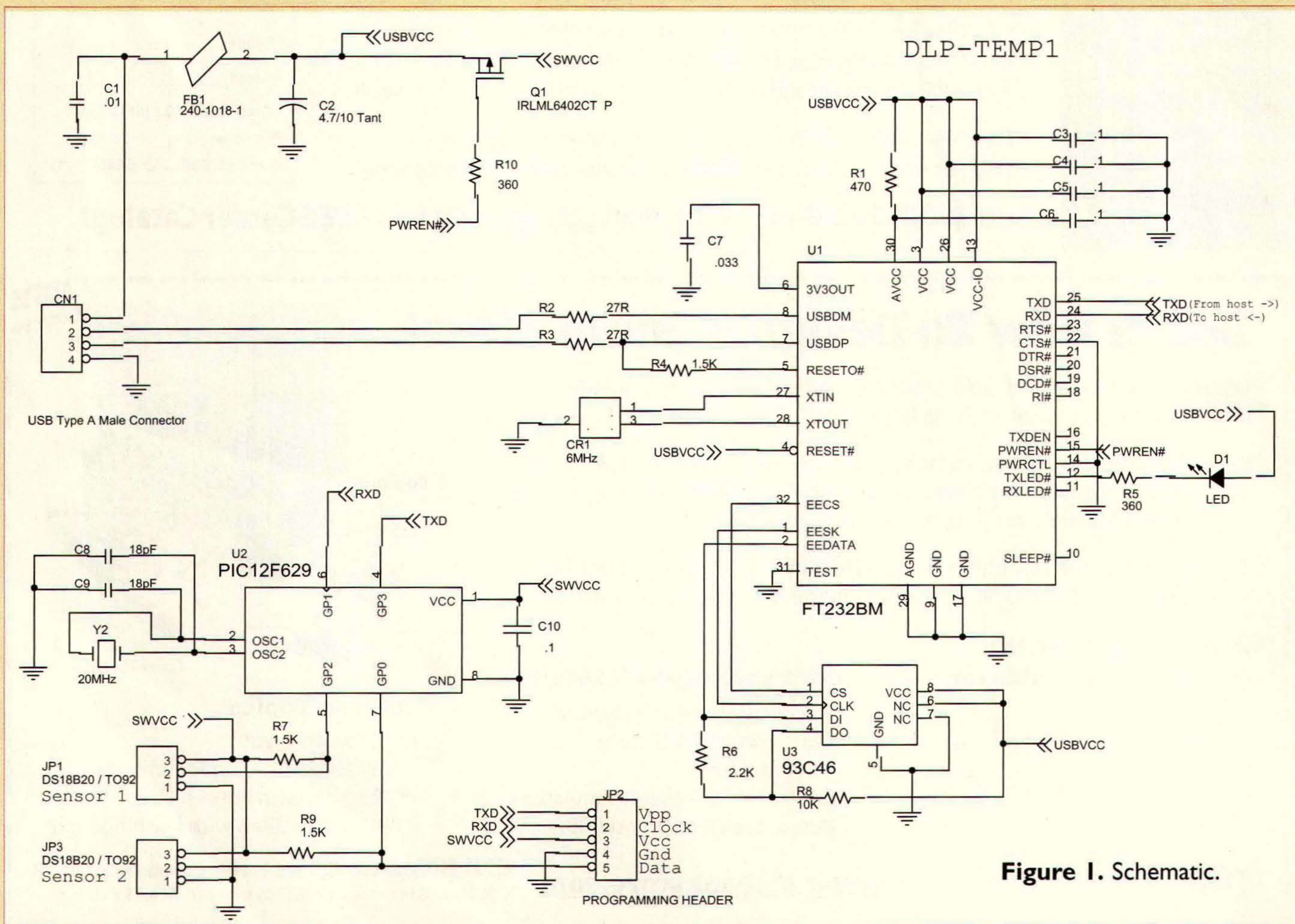


Figure 1. Schematic.

two free port pins on your microcontroller? The serial version of their chip presents an industry standard RS-232 interface (RX, TX, CTS, RTS, etc.) for easy connection to a legacy RS-232 device. All that is typically needed to connect a legacy RS-232 device to the FT232BM is a garden-variety receiver/driver IC (MAX-232, HIN232, etc.) and a DB9 connector. Using the FT232BM USB-UART chip instead of the parallel version frees up 10 micro port pins for use in your project.

For this project, we will interface the FT232BM directly to an eight-pin, PIC 12F629 Flash-based microcontroller. Two of the micro's pins connect to a 20MHz crystal, two are used for power and ground, two for communicating with a host PC (TX and RX), and two for talking to a pair of Dallas Semiconductor DS18B20 digital temperature sensors. Refer to Figure 1 for the schematic.

The micro only has 1K of ROM and, surprisingly, the firmware for this project only required 54 percent of the available ROM thanks to PCM, a highly-optimized C compiler from CCS (**www.ccsinfo.com**). Since the micro is Flash-based, and a programming header is included in the design, the firmware can be easily updated (or replaced by your own code) without having to remove the micro from the board. And that's significant for this design since the micro we've selected is in an SOIC8 surface-mount (i.e., no socket) package.

All that is needed to interface to each DS18B20 is a single port pin and a pull-up resistor. Neither the micro nor the DS18S20 ever drive the port pin high. The only time it is high is when neither is driving it low. An open collector (or in this case, open drain) port pin on the micro would be perfectly suited for this application. However, since this design doesn't have one available, the software will have to pick up the slack. The functionality of an open drain output can be easily simulated by toggling the port pin between input and output low. When the port pin is configured as input, the pull-up resistor pulls the data line high.

The design presented in this article shows how to interface two temperature sensors to the USB port. It could have just as easily demonstrated how to interface two switches, two outputs (for driving relays, LEDs, etc.), or a mix of the two. Also, a larger micro, like the 16F84A, could have been used for more port pins.

Programming the 12F629 Flash-based micro is accomplished via a five-pin header that consists of power and ground, clock, data, and a programming voltage of about 12.5 volts. For this project, I used the EPIC Plus Programmer (**www.melabs.com**). You will have to make your own programming cable using both five-pin and 10-pin headers in order to make the connection to the programmer. Keep in mind that Sensor 2 must be disconnected from the board during firmware upload so that it does not interfere with the programming process.

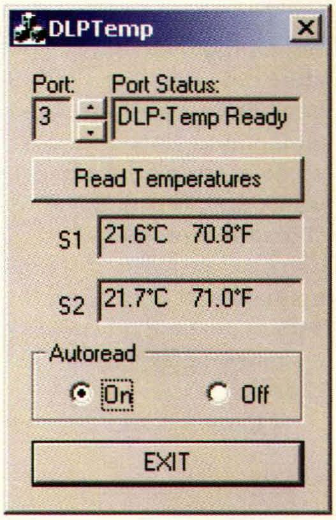


Figure 3. Visual C++ and Visual Basic Demonstration Program.

```
void main()
{
        int8 byte_read;

        start_convert();//start conversions on both sensors
        while(1)//continuous loop
        {
                while( !kbhit() ) //while nothing received
                        RESTART_WDT(); //pet the dog
                byte_read = getc(); //read one byte from host
                via USB

                if(byte_read == 'P') //if byte_read is 'P' then
                send response 'Q'
                        putc('Q');

                //don't call this function more than once per
                second...
                if(byte_read == 'R') //if byte_read is 'R' then
                read
                        read_convert(); //both devices and
                        start new conversion

                byte_read=0;
        }
}//end of main()
```

Figure 2. Source code for main().

VIRTUAL COM PORT DRIVERS

The Virtual Com Port (VCP) drivers make your USB-

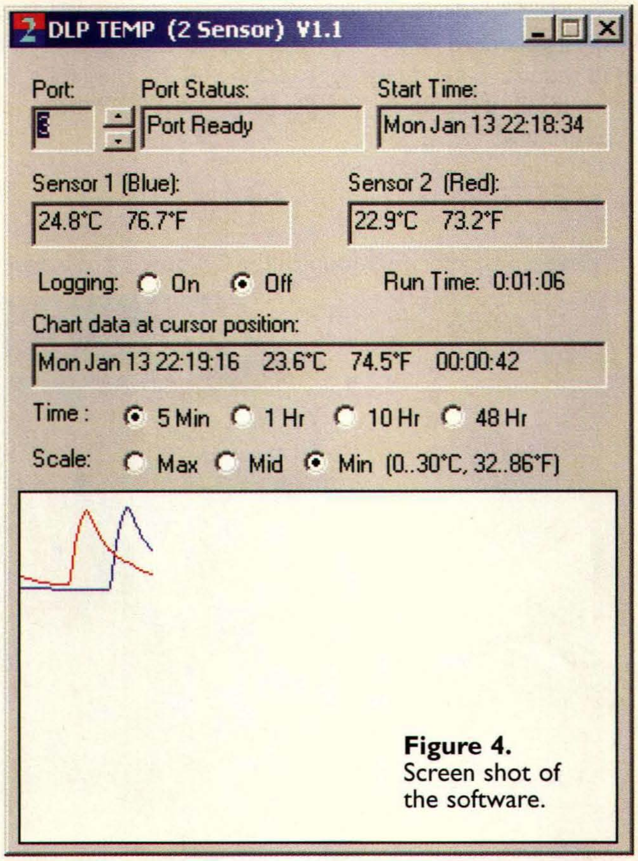
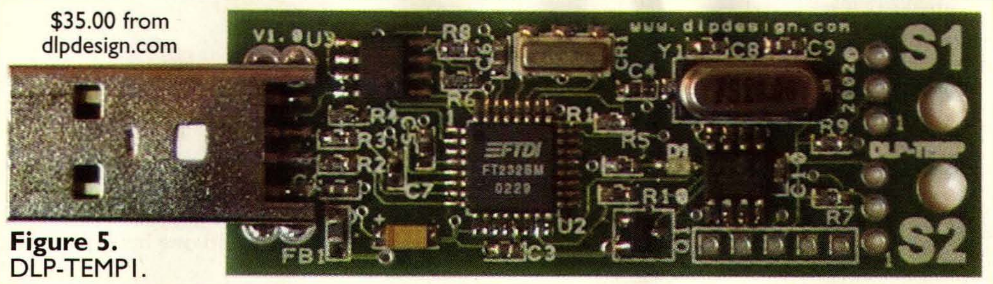


Figure 4. Screen shot of the software.



$35.00 from dlpdesign.com

Figure 5. DLP-TEMP1.

based product appear to your Windows application as though it is connected to an RS-232 port. Your application simply opens a com port and sends data as though it were going to the DB9 connector on the back of the PC. If your application opens a com port that is assigned to the VCP drivers (via the Device Manager window), then the data bytes sent are redirected to the USB scheduler and then out the USB port. Any data returned to the host via USB simply appears in the buffer that was created when your application opened the RS-232 port.

Some things you won't have to worry about are USB-related details like endpoints, token packets, data packets, handshake packets, ACKs, NACKs ... the list goes on and on. The VCP drivers do a splendid job of hiding these details from the user. The desired baud rate, number of data bits, stop bits, and parity selection for the data sent from the FT232BM USB chip to the target electronics can be set by the host application. Setting these parameters in the host application has no effect on transmitted USB data packets.

The maximum data rate that can be expected using the FT232BM is somewhere in the neighborhood of 1-3 megabaud (depending on how your circuit is configured), and all standard baud rates are supported. Applications that require data rates approaching eight megabits per second fall more under the purview of the FT245BM and DLL drivers.

FIRMWARE

The complete microcontroller C source code listing for this project can be downloaded from **www.dlpdesign.com/usb/temp.html**. The main() function is shown in Figure 2. As you can see, in this implementation there are only two commands for communicating with the microcontroller. The first is a "ping" command for detecting the presence of the board and microcontroller. This command can be used by the host application to help locate the COM port to which the micro is connected. The second command calls a function that reads the temperature data from both of the temperature sensors, sends 18 bytes of temperature data back to the host, and calls another function [start_convert()] that starts the next temperature conversion. Note that the start_convert() function is called at power-up so that temperature data is ready for read the first time the "R" command is issued.

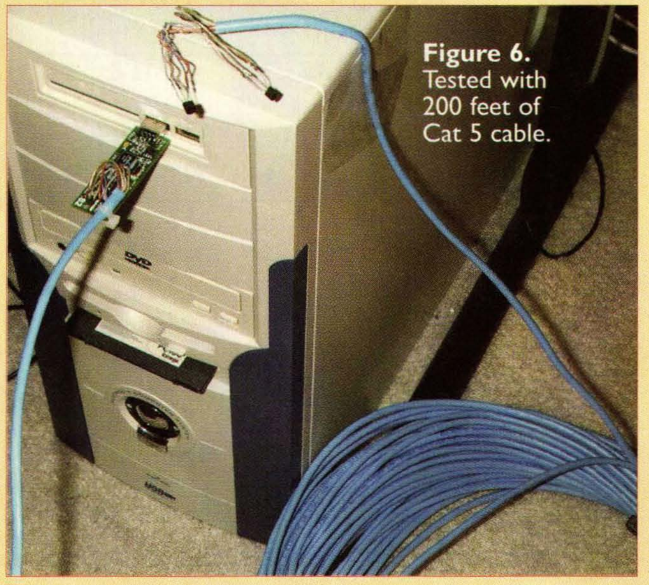


Figure 6. Tested with 200 feet of Cat 5 cable.

The code in main() will wait — continuously resetting the watchdog timer — until port pin GP3 is pulled low by the USB chip indicating the start of an incoming serial character. The getc() function is then called to receive the character. Error correction (crc, checksum, etc.) could be added, if desired, to make the interface more bulletproof.

The DS18B20 temperature sensors take up to 750 milliseconds to perform a full 12-bit temperature conversion and write the data to their internal scratch pad memory. For this reason, there is no reason for the host application to issue the "R" command more than about once per second. Additional firmware could be added to the micro to allow for nine-bit temperature conversions so that much faster temperature measurements (less than 95 milliseconds) can be performed in the DS18B20. Keep in mind that faster readings come at a price. As the speed goes up, the accuracy goes down. (Refer to the DS18B20 datasheet for details.)

WINDOWS SOFTWARE

The source code for simple Visual C++ and Visual Basic programs that demonstrate how to read the temperature data from the 12F629 micro can be downloaded for free from **www.dlpdesign.com**. The code will request the temperature data once per second, convert the nine bytes of data returned from each sensor to a floating point value, and display those values. Figure 3 shows a screen shot of this program.

Also available is a Windows application that will read the data and both chart the data graphically and log the data to the hard drive. This program can be purchased for a shareware level fee of $20.00 ($13.00 with another purchase).

Figure 4 shows a screen shot of this software.

PCB

Figure 5 shows the printed circuit board for this project and just how small a complete USB product can be made using the USB chips from FTDI. The bottom layer of this two-layer board is mostly a ground plane to help keep the noise and EMI to a minimum. The board comes with one sensor. The sensor is not soldered to the board so that the user has the option of locating the sensor at a distance from the board using Cat 5 cable. This design has been successfully tested with both sensors located 200 feet (Figure 6) away from the board using Cat 5 cable.

Two pairs of wires in the Cat 5 cable are required for the connection — one pair for power and ground, and the other pair for data and ground. If using both sensors, you can either connect them to the board using one cable for both sensors (since the cable has four pairs), or two cables if the sensors are to be placed in different locations.

Since this design incorporates a male Type A USB plug, it can be directly plugged into the PC's USB port. If you want to bring the board up to your workbench while still communicating with the board, then a USB extension cable can be used.

POWER CONSIDERATIONS

The five volts from the USB port are used to power both the circuitry on the PCB, as well as the two temperature sensors. This does not mean to imply that the USB port can supply unlimited current to your external circuitry. The maximum current that can be drawn from the port is 500 milliamps. This assumes that the board has been configured as a high-powered device. This also assumes that the board is connected to a port on the PC or powered hub. If connected to a self-powered hub, then the maximum power available for use is reduced to a total of just 100 milliamps.

When the board is first connected to the host PC, the maximum current that can be drawn is 100 milliamps. After enumeration is complete, the board can draw the full 500 milliamps. To prevent drawing excessive current before enumeration, this design includes a MOSFET transistor to switch the power going to the micro and sensors. The switch is controlled by the PWREN# signal from the FT232BM.

CONCLUSION

While FTDI's drivers and chips do relieve the developer of having to learn 95 percent of what can be learned about USB, I still recommend getting a good book on the topic, like Jan Axelson's *USB Complete Second Edition* (**www.lvr.com**) if for no other reason than to become familiar with the complexity of USB and to develop realistic expectations of USB's capabilities. For instance, USB Specification 1.1 proclaims a data rate of 12 megabits per second. In reality, the actual data throughput for a full-speed device in bulk transfer mode is closer to a maximum of eight megabits per second, once you add all of the overhead involved in making USB usable and reliable.

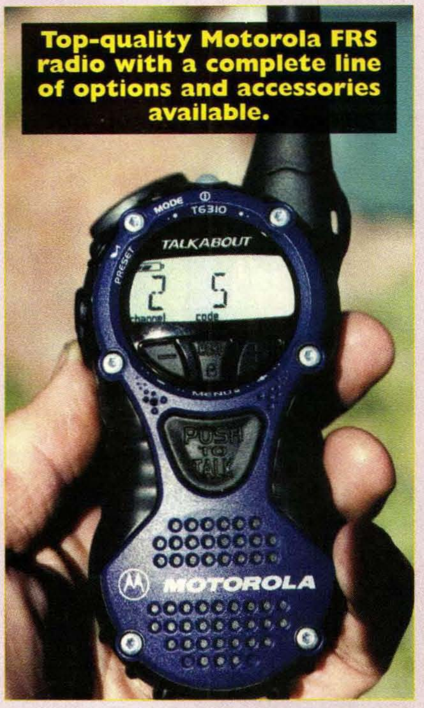
If your project calls for higher data throughput, or if you would prefer working with a parallel interface and have the required number of micro port pins available, additional reading on using the FT245BM is available online at **dlpdesign.com/pub.shtml**.

USB-based product development really is within reach for those of us (myself included) who don't have the ability to develop device drivers. While I'm almost always intrigued by the challenge of learning something new, the ever-approaching deadline always seems to win out over my desire to take on a new grand venture. So, if you want to learn how to write device drivers (a noble venture indeed, and one that might well increase your salary once mastered!), then pick up a book on the topic of WDM device drivers and start reading. If you want to get your new USB-based product to market on time, then have a look at FTDI's chips. I think you'll be glad you did! NV

FRS RANGE WARS

by Gordon West

The distinction between must-license and no-license handheld radios is getting blurred as more and more options become available from manufacturers.



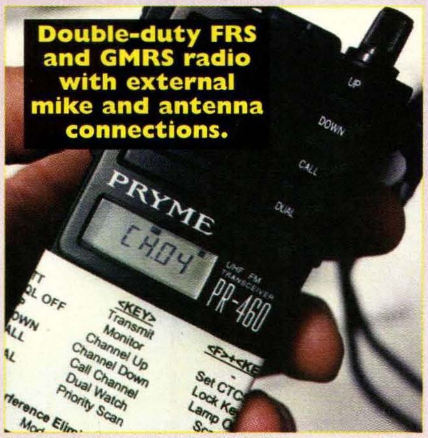
Top-quality Motorola FRS radio with a complete line of options and accessories available.

The distinction between must-license and no-license handheld radios is becoming blurred by the radio range wars going on between competing manufacturers and dog-fights at the dealer level.

"For $29.95, you go one mile. For $39.95, you have two miles. For $79.95, you can get five miles," reports a salesman at Fry's Electronics. No mention of the required license for GMRS operation. And the only difference between the $29.00 and $39.00 FRS units with one- and two-mile range, was that the less expensive unit did not have the page vibration alert feature. And I guess this cut its communications range by half?

"Just give yourself a boat name and you are all set to go with 10 miles range," comment the sales personnel at a tackle store in the northeast that offers snow mobilers accessory equipment in the wintertime. We were told that the 25-watt, marine VHF, fixed-mount transceiver could be used *anywhere,* including on a snow mobile or in a vehicle, because the Federal Communications Commission (FCC) had eliminated marine radio licensing. Absolutely untrue — although the FCC has indeed eliminated the need for a ship station call sign to operate marine VHF in domestic waters, marine Part 80 FCC rules are clear that the equipment may only be operated on navigable waters. It takes a special marine coast station license to operate marine VHF from shore-to-ship, and *never* between two land stations running 25 watts on marine ship-to-ship channels.

The range wars on small handhelds escalate with Family Radio Service equipment now sporting a much taller, fixed, UHF rubber duck antenna.



Double-duty FRS and GMRS radio with external mike and antenna connections.

"Our new 4088A Family Radio Service handheld radio offers extended communication range because of its high-performance antenna," reports ICOM America at a recent boat show. While I agree an elevated UHF feed on a rubber duck antenna is technically superior to the little, short, helical antenna, "extended communications range" would probably not double, as some consumers might think. But good for ICOM America — they didn't claim any FRS range in miles — and since ICOM America sells quality marine communications equipment, a half-watt over sea water during periods of still-air tropospheric ducting could lead to a whopping 20 miles, if one station is up on a hill!

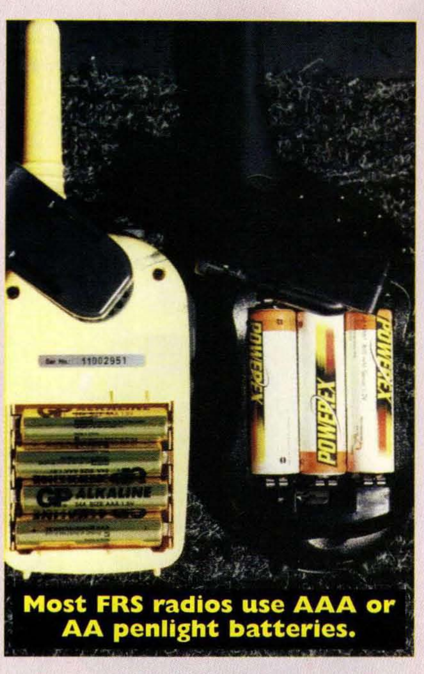
It gets better yet — Standard Horizon, the marine division of the land mobile radio company Vertex, and amateur radio company Yaesu, were seen previewing a submersible tri-band marine portable radio, Model HX470S, capable of five watts on marine VHF, two watts on Multi-Use Radio Service (MURS), and the customary legal limit — one-half watt on UHF Family Radio Service, plus AM radio, FM broadcast radio, NOAA weather band radio, and AM aircraft receive-only capabilities. Mind you, all this in one nice, neat unit fully submersible.

Standard Horizon cautions that this radio is not offered for sale nor is FCC type-accepted, and best considered a "concept radio," although it is far beyond the conceptual stage. I am told it has just received Canadian approval, and they hope that the FCC approval process will be coming shortly. And technically, the radio absolutely can work as conceived (not advertised for sale!) because the Yaesu triple-band amateur handheld radio, Model VX-7R, appears to be a blood-brother to the new HX470S. *Repeat* — numerous boat show disclaimers illustrate a concept radio not FCC approved for sale.

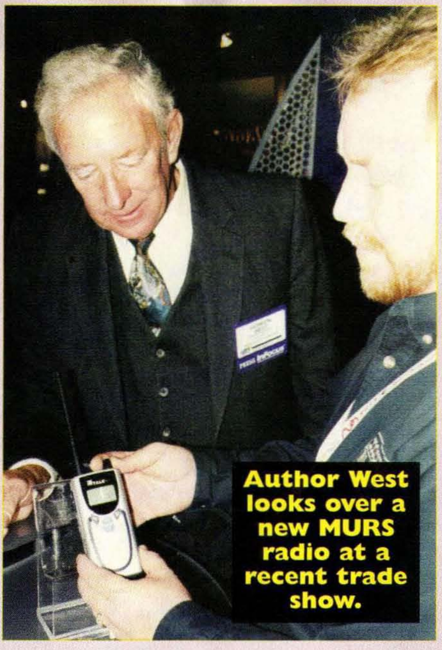
But the concept makes sense — a single radio that may offer all of the advantages of no-license MURS, FRS, and marine VHF operated on navigable water with specific marine rules on what VHF channels may be used for specific types of on-water communications.

"The focus on expected range for XX amount of dollars has misdirected buyers on the requirement for certain FCC licenses," comments Bill Alber, a Bay Area marine electronics communications specialist.

"The issue of a required Federal Communications Commission license becomes more cloudy when you talk about an FRS radio with extended range GMRS frequencies," adds Alber, referring to the operating manual which



Most FRS radios use AAA or AA penlight batteries.



Author West looks over a new MURS radio at a recent trade show.

points out that the eight GMRS channels included are repeater output frequencies, not actual repeater input/output channels. This leads many buyers to believe no license is required for GMRS "talk around" output frequencies, even though the rules are clear that any operation on GMRS channels requires the $75.00, five-year license.

"There is no telling how many consumers are operating on GMRS channels without the appropriate license," comments well-known communications authority Bob Leef, in Mission Viejo, CA. Leef has over 40 years in communications electronics, and is one of the most knowledgeable communications consultants for many cities in Southern California who are starting up volunteer emergency communication groups using Family Radio Service equipment. Leef has established many emergency groups, including those serving REACT, and invites *Nuts & Volts* readers to pick up some "free advice" on the legal use of handheld radios by logging onto **www.rkleef.com**.

FRS RADIOS BY THEMSELVES

These straightforward radios generally put out slightly less than a half-watt of power, and the antenna is non-removable by FCC order. I use a nearfield field strength meter to determine approximate power output levels, and I note that even the "two pair for $29.00 with a manufacturer $29.00 rebate certificate" seems to have about the same amount of field strength as a much more expensive single FRS unit with plenty more features. (Yup, act quick and you can buy a pair of FRS radios for virtually free!)

But the features really make a difference on FRS equipment. Inexpensive FRS gear usually exhibits low volume and feeble audio fidelity out of the little speaker, whereas more expensive FRS equipment tends to give you much louder volume output and capabilities of CTCSS tone to include voice encryption. Many buyers will purchase equipment and turn on the "privacy" tone feature, thinking that they are now in the scrambled mode — they are not. They are simply decoding CTCSS, and the only privacy they get is less people coming through on the same channel they have dialed up because the receiver is tone squelched to one of 38 pre-selected tones.

A little more money on a quality FRS radio leads to vibration alert, voice encryption, VOX headset capabilities, and a host of very useful features. But range extension with more money spent — it won't happen. I think the ICOM America new extended antenna is about the only way you might squeak out a few extra hundred yards of communications range. Mileage range figures for FRS equipment are absurd — downtown you might barely get a block, but out on the desert from mountaintop to mountaintop on a windless hot day with tropospheric ducting at its best, you might even do 50 miles!

MULTI-USE RADIO SERVICE

Now that the FCC has clarified rules on this VHF service at two watts maximum output, equipment is beginning to pop up. Most MURS equipment offers all five VHF channels, original frequencies assigned to the Part 90 business radio service "color dot" channels:

151.820 MHz
151.880 MHz
151.940 MHz
154.570 MHz
154.600 MHz

These channels now fall under the CB radio rules for multi-use radio service — license free, under Part 95, Subpart J. This allows two watts output, narrow-band FM, and an outside antenna permissible to boost range dramatically.

This external antenna rule is a good one — you can go 20 feet above anything on your roof, not to exceed 60 feet above the ground. A two-watt transmitter into low-loss, LMR-400, professional, land mobile radio coax cable to a 10 dB gain, collinear, vertical antenna would legally boost effective radiated power to about 20 watts. Incoming signals would also increase by 10 dB, and you could establish VHF communications range on a clear channel easily up to 10 miles base-to-mobile, and 20 miles base-to-base.

But the problem is "clear channel" — I doubt you will find one. Thousands of users throughout the country have been buying "color dot" VHF radios for all sorts of purposes, and few ever went through the FCC licensing process, although it *was originally* required under Part 90. When the color dot radios began showing up at electronic outlets and major superstore chains, the five channels quickly loaded up with unlicensed operators. Now that the channels are license-free, interference will be at an all-time high in major cities.

But MURS out of town in rural areas offers great VHF range capabilities on a vacant channel — if you can find one. Make sure you buy a radio with CTCSS decode because you're going to need it to keep your equipment quiet from many co-channel users. The FCC has attempted to keep the new MURS band orderly, and has clarified rules to prohibit in-band repeaters, time-delay repeaters, and prohibit tying into a telephone patch. There was also talk about what the FCC would require for product identification on the back of the equipment, and there might even be rulemaking that would limit the MURS handheld to five exclusive channels only, not sharing the handheld with any other radio service.

FRS/GMRS

Now we really get into "fuzzy" frequencies — mixing two distinct radio services into one nice, neat handheld.

Family Radio Service half-watt, 2.5 kHz deviation channels equal 14 frequencies. The first seven are interstitial between eight GMRS repeater output frequencies. This is why on an FRS radio, you may hear "bleed over" on the first seven channels from repeater outputs in your operating area. Some GMRS repeaters may run up to 50 watts output into a 10 dB gain UHF antenna. That works out to be 500 watts ERP, just 12-1/2 kHz away from anyone of the first seven channels on FRS. No wonder you are getting hammered at the theme park by something off frequency!


Computer loading UHF channels in a FRS/GMRS radio from Kenwood.

FRS channels 8 through 14 are favorites because they are interstitial to GMRS input frequencies. Unless you're standing right next to someone operating through a GMRS, you wouldn't know of interference that couldn't be tuned in or tuned out.

GMRS channels number 8, and repeaters output low (462 MHz), and input licensed repeater users transmit five MHz high (467 MHz). If, and only if, the GMRS radio user files electronically with the FCC and achieves the five-year, $75.00 license, the license permits eight channels of GMRS duplex operation, plus eight channels of "talk around" GMRS repeater output simplex communications, *plus* seven channels of interstitial repeater output simplex operation *shared* with channels 1 through 7 FRS. You can imagine the collision — a half watt, 2.5 kHz (plus or minus) deviation FRS signal getting hammered by a five kHz two-watt signal hammering the FRS half-watt. GMRS licensees share those same first seven FRS frequencies.

Bob Leef talks about a radio that can do it, too, providing the operator indeed holds a GMRS license.

"The Motorola T7200 offers 14 FRS channels, plus eight GMRS repeater talk-around channels, plus eight GMRS repeater duplex channels," comments Leef, pointing out that using a mountaintop GMRS repeater normally requires the correct subaudible tone plus explicit permission from the repeater owner. Leef also points out that GMRS repeater (as well as simplex output talk-around) use should be limited to professional radio traffic, not just idle gab that would normally take place on any of the 14 FRS frequencies. Leef further points out that FCC licensing can be accomplished at the FCC website at **www.fcc/wtb/uls**.

Well-respected organizations like the Personal Radio Steering Group (PRSG) are very concerned about marketing tactics that promote longer range capabilities on GMRS channels.

"What people are buying is two-mile range and five-mile range, so they are looking at the range, not whether it is GMRS or FRS," comments John Normand, communications buyer for K-Mart in an interview with *Twice Magazine*.

"People don't care what type of radio service they are talking on — they are only concerned about range and clarity," adds Bill Alber. He points out that most no-license radio buyers assume that any radio purchased at a regular retail store would have no licensing requirements nor any specific rules on how the radio would be operated. It would also be assumed that "more professional FCC license required" radios would only be available from a professional two-way radio commercial dealer. Not necessarily so.

Leef, at his **www.rkleef.com** website, assists buyers to better understand what the radios can do, and what they may be legally used for when operated on the air with or without a license. His handheld comparison chart does a nice job of making the technical easier to understand by the first-time radio user.

Well-respected marine electronics radio manufacturer, Garmin, goes one step further on FRS and GMRS output frequencies, offering Global Positioning System (GPS) position and direction finding. They are working under an FCC waiver to give this system a test — you ask your friend with a similar Garmin RINO FRS/GPS radio where they are, and they push a button and a datastream comes over the same channel they are talking on to command *your* Garmin RINO radio to show their position on the screen. Their position might show up as an icon near you, or show up with a base map so you might more logically find out where they are located. The rule waiver did not allow them to make this a fully automatic function, but nonetheless, ask Suzy where she is, and with a Garmin RINO radio, she pushes a button and it shows up on your screen as a quarter mile away dead ahead. That is, dead ahead if *your* GPS detects that you are moving and can determine what direction you are going. Keep in mind that a GPS without a built-in fluxgate compass cannot determine direction when standing still with a single antenna. Everyone else on FRS would simply hear a databurst containing the position information.

Now there is talk that the FCC may also open up additional no-license frequencies on selected UHF land mobile itinerant and color dot frequencies. Time will tell. But one thing for sure at the marketplace — millions of buyers are turning into radio users when they see the many benefits of short-range, license-free communications at relatively inexpensive prices. And if you hurry down to your local electronics store, cash in on the pair of $29.00 FRS handhelds that come with a $29.00 manufacturer rebate. Pretty good deal for just the price of sales tax! Yes indeed, license-free radios are an inexpensive way to stay in touch! NV

Elenco's Electronic Snap Circuits

by Fred Blechman

Learning electronics is a snap with these educational kits.

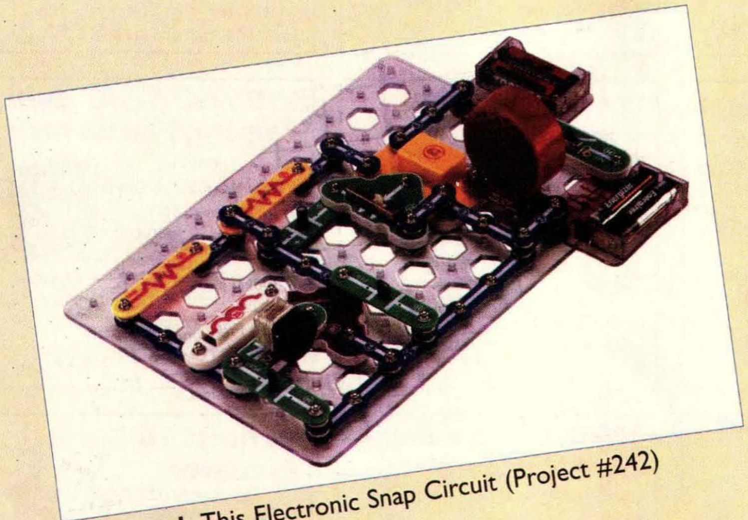


Figure 1. This Electronic Snap Circuit (Project #242) is an AM Radio.

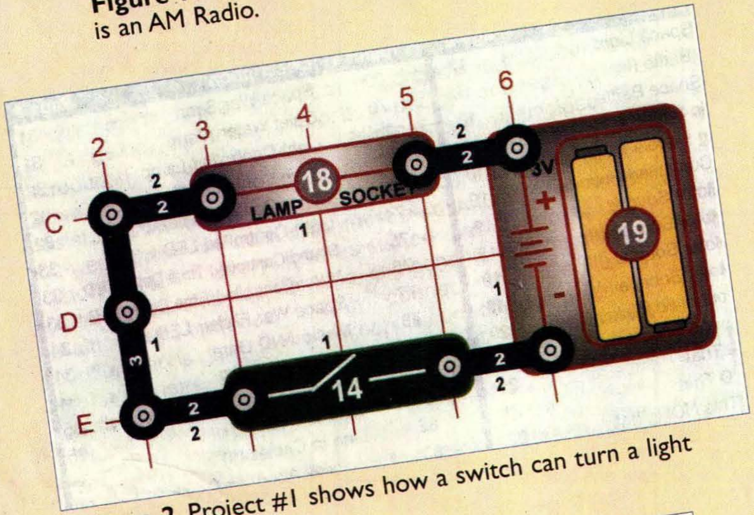


Figure 2. Project #1 shows how a switch can turn a light on or off.

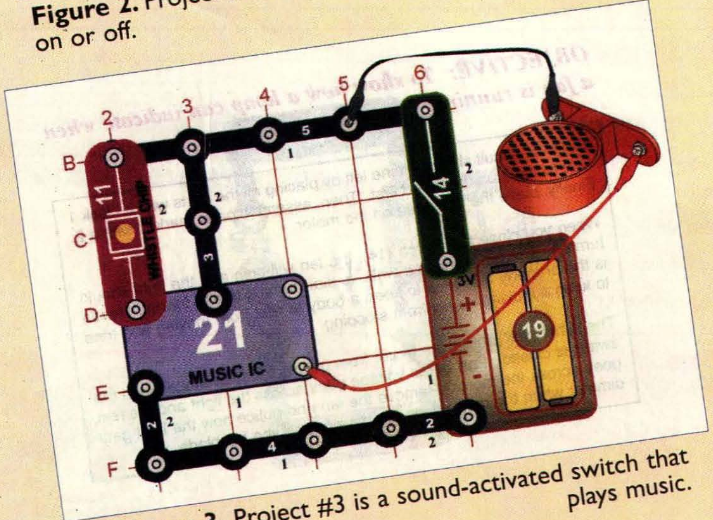


Figure 3. Project #3 is a sound-activated switch that plays music.

Back in the late 1930s and early 1940s, when I had become old enough to read, write, walk, talk, and chew gum at the same time, I became fascinated with simple mechanical and electrical toys. Not only did I have an Erector Set, Tinkertoys, and Lincoln Logs (no Lego Bricks in those days) — and, of course, a Lionel toy train layout — but I also had a bunch of switches, bells, buzzers, and small lights.

When I wasn't building a bridge with my Erector Set, or a spindly airplane with the Tinkertoy spools and sticks, I would make up simple battery-operated "burglar-alarm" circuits. Or play with a "cat's whisker" on a galena crystal using a high-impedance earphone and a bedspring for an antenna to listen to local radio stations. Technology at the time was simple. And I learned to have a great respect for 117 volts AC when I decided one day to cut a line cord that was plugged into the wall! E-e-o-o-o-w-w-w!

But these days it's difficult for a child — or even an adult — to learn the very basics of electronics. In the "old days," the basic electronic components were resistors, capacitors (we called them "condensers" then), inductors, and vacuum tubes. Then selenium and silicon rectifiers came along. But today, with the advent of a bewildering array of transistors, integrated circuits, microprocessors, and microcontrollers, it is more a matter of properly arranging and interconnecting modular parts to form complete devices.

And so it is not surprising that Electronic Snap Circuits™ have now become available. Elenco Snap Circuit Kits use building blocks that snap onto a plastic base and snap together to form complete electrical and electronic circuits. No tools are needed, and no soldering is involved. Each block has a switch, resistor, capacitor, inductor, diode, transistor, integrated circuit, lamp socket, microphone, motor, or speaker — or maybe for the purpose of connecting between parts. The blocks are in different colors and have numbers on them so they are easily identified. The "conductor" connecting blocks come in different lengths. Some circuits use supplied alligator-clip jumper wires to make unusual connections. This will all become clear as example circuits are shown later in this article.

An included large clear plastic base grid has evenly spaced posts for the different blocks to snap onto. To help in assembly, the base has rows labeled A-G, and columns labeled 1-20 to agree with the clear, colored diagrams provided for each "project" (circuit). The diagrams also indicate at which "level" a block is placed, since blocks can snap above each other. Level 1 blocks go on the grid first, then Level 2 parts snap onto Level 1 parts, then Level 3, etc. It's really very simple and easy to follow from the excellent project diagrams.

Each project is powered by two "AA" batteries, so there is no danger involved — although while building the projects, be careful not to accidentally make a direct connection across the battery holder (a "short circuit"), since this will quickly drain the batteries.

Look at Figure 2 (Project #1) to get the idea of a simple snap circuit to show how electricity is turned on and off with a switch. First notice the grid locations: C-E and 2-6. Note that each block has an identifying number on it. The blocks with a small black number next to them are snapped onto the plastic grid first at the grid locations shown.

In this project, Number 19 Battery Holder, Number 18 Lamp Socket, Number 14 Switch, and Number 3 Three-Snap Conductor are snapped onto the grid first. Then four Number 2 Two-Snap Conductors are snapped on the already installed parts, and the circuit is complete. Add the batteries (polarity as shown) in the holder, screw the supplied bulb into the lamp socket, and close the switch. Current flows from the batteries through the switch and the bulb in this "closed" circuit, and the bulb lights. Turn the switch off and the light goes off because the circuit is now "open."

Of course, the projects get more complex and more interesting — 100 projects in the smaller kit (see below) and 300 projects in the larger kit. Just follow the colorful diagrams in the Instruction Manuals and you can build an AM radio, various types of alarms and motorized toys, flashing lights, doorbells, logic circuits, games, and much more.

Figure 3 shows Project #3, a Sound Activated Switch. A MUSIC IC (integrated circuit) plays music through the speaker when the Whistle Chip is tapped or activated by sound. While no schematics of the circuits are provided, so there is some "mystery" about how the solid-state integrated circuit blocks are connected, children and adults from 8 to 108 can enjoy hours of educational fun while learning about some basic electricity and electronics. It could be the first steps for a budding Alexander Graham Bell, Thomas Edison, Nikola Tesla ... or Bill Gates!

A kit of 30 parts (Model SC-100) with an Instruction Manual to build over 100 projects sells for $29.95. A larger kit, with 60 parts (Model SC-300) and two Instruction Manuals for a total of 300 projects sells for $59.95. The source is C&S Sales, Inc., 150 W. Carpenter Avenue, Wheeling, IL 60090. Phone is (800) 292-7711. Their website is **www.cs-sales.com**. NV

UNDERSTANDING AND USING 'OTA' OP-AMP ICs

by Ray Marston

Part 2

Ray Marston looks at the operating principles and practical applications of the LM13700 dual Operational Transconductance Amplifier (OTA) IC in this concluding episode of a two-part mini-series.

Last month's opening episode of this two-part mini-series described basic 'OTA' operating principles, and took a close look at the popular and widely available CA3080 OTA IC. The CA3080 is actually a simple, first-generation OTA that generates fairly high levels of signal distortion and has a high-impedance unbuffered output. This month's concluding episode describes an improved second-generation OTA IC — the LM13700 — which does not suffer from these snags.

The LM13700 is actually a dual OTA, as indicated by the pin connection diagram in Figure 1. Each of its OTAs is an improved version of the CA3080, and incorporates input linearizing diodes that greatly reduce signal distortion, and have an optional buffer stage that can be used to give a low impedance output. The LM13700 is, in fact, a very versatile device, and can easily be made to act as a voltage-controlled amplifier (VCA), voltage-controlled resistor (VCR), voltage-controlled filter (VCF), or voltage-controlled oscillator (VCO), etc.

LINEARIZING DIODES

The CA3080 OTA consists of (as described last month) a differential amplifier plus a number of current mirrors that give an output equal to the difference between the amplifier's two collector currents, as shown in the simplified circuit in Figure 2. A weakness of this circuit is that its input signals must be limited to 25mV peak-to-peak if excessive signal distortion is not to occur. This distortion is caused by the inherently non-linear V_{be}-to-I_c transfer characteristics of Q1 and Q2.

Figure 3 shows the typical transfer characteristics graph of a small-signal silicon transistor. Thus, if this transistor is biased at a quiescent collector current of 0.8mA, an input signal of 10mV peak-to-peak produces an output current swing of +0.2mA to -0.16mA, and gives fairly small distortion. But an input swing of 30mV peak-to-peak produces an output swing of +0.9mA to -0.35mA, and gives massive distortion. In practice, the CA3080 gives typical distortion figures of about 0.2% with a 20mV peak-to-peak input, and a massive 8% with a 100mV peak-to-peak input.

Figure 4 shows the basic 'usage' circuit of one of the improved second-generation OTAs of the LM13700, which is almost identical to that of the CA3080, except for the addition of linearizing diodes D1 and D2, which are integrated with Q1 and Q2, and thus have characteristics matched to those of the Q1 and Q2 base-emitter junctions. In use, equal, low-value resistors — R1 and R2 — are wired between the inputs of the differential amplifier and the common supply line, and bias current I_D is fed to them from the positive supply rail via R3 and D1-D2 and, since D1-D2 and R1-R2 are matched, divides equally between them to give R1 and R2 currents of $I_D/2$.

The circuit's input voltage is applied via R4 (which is large relative to R1) and generates input signal current I_s, which feeds into R1 and thus generates a signal voltage across it that reduces the D1 current to $(I_D/2) - I_s$. The I_D current is, however, constant, so the D2 current rises to $(I_D/2) + I_s$. Consequently, the linearizing diodes of the Figure 4 circuit apply heavy, negative feedback to the differential amplifier and give a large reduction in signal distortion. If I_s is small relative to I_D, the output signal current of the circuit is equal to $2 \times I_s \times (I_{bias}/I_D)$. Thus, the circuit's gain can be controlled via either I_{bias} or I_D.

The OTAs of the LM13700 can be used as simple OTAs of the CA3080 type by ignoring the presence of the two linearizing diodes, or can be used as low-distortion amplifiers by using the diodes as shown in Figure 4. The graph in Figure 5 shows typical distortion levels of the LM13700 at various peak-to-peak values of input signal voltage, with and without the use of linearizing diodes. Thus, at 30mV input, distortion is below 0.03% with the diodes, but 0.7% without them, and at 100mV, input is roughly 0.8% with the diodes, but 8% without them.

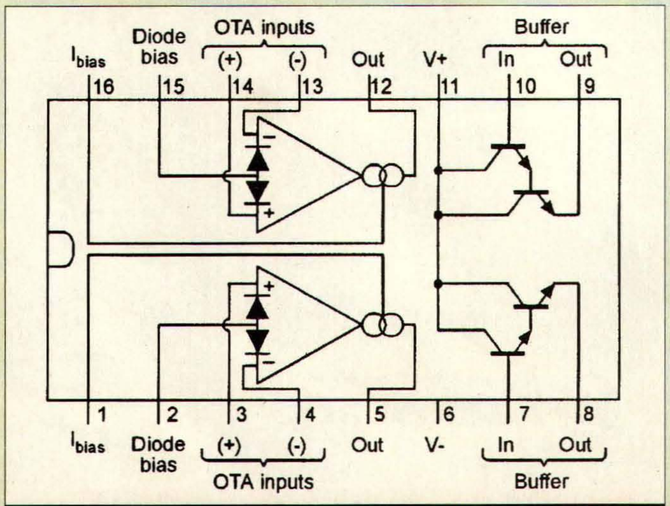


Figure 1. Pin connections of the LM13700 dual OTA IC.

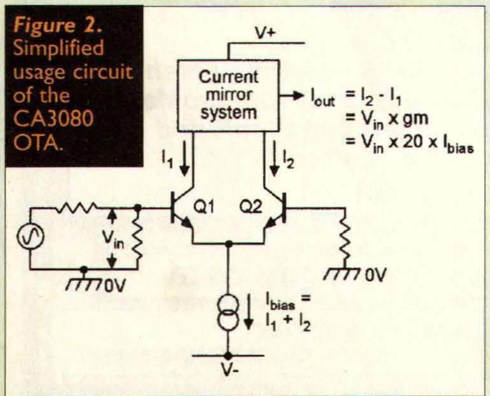


Figure 2. Simplified usage circuit of the CA3080 OTA.

INTERNAL BUFFERS

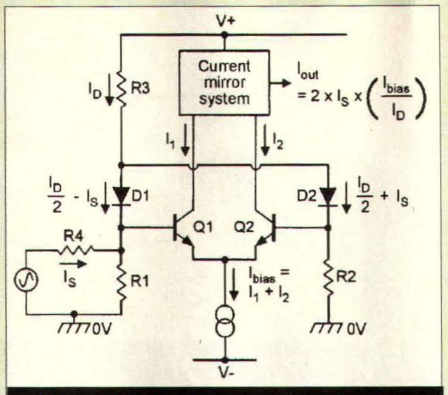


Figure 4. Simplified usage circuit of an LM13700 OTA.

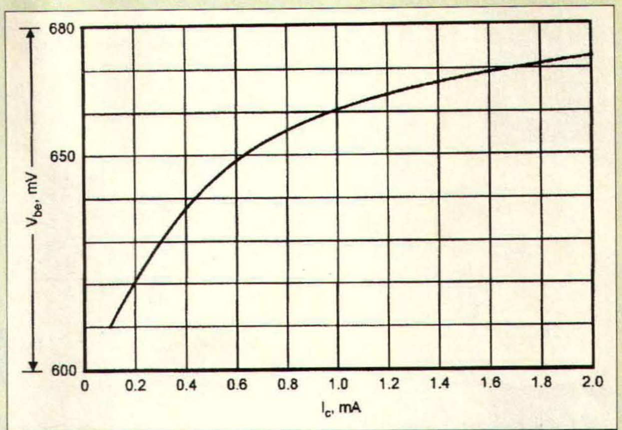


Figure 3. Typical transfer characteristics of a small-signal silicon transistor.

Figure 6 shows the internal circuit of each half of the LM13700 IC package. If this circuit is compared with that of the CA3080 shown last month, it will be seen to be broadly similar except for the addition of linearizing diodes D1-D2 to the inputs of the OTA's Q1-Q2 differential amplifier, and the addition of output transistors Q11-Q12, which are configured as a Darlington emitter follower buffer stage and can (by wiring its input to the OTA output and connecting Q12 emitter to the negative rail via a suitable load resistor) be used to make the high-impedance output of the OTA available at a low-impedance level. Note in this latter case that the output of the buffer stage is two base-emitter volt drops (about 1.2V) below the output voltage level of the OTA, so this buffer is not suited for use in high-precision DC amplifier applications.

The two OTAs of the LM13700 share common supply rails, but are otherwise fully independent. All elements are integrated on a single chip, and the OTAs have closely-matched characteristics (gm values are typically matched within 0.3dB), making the IC ideal for use in stereo VCA and VCF applications, etc. The standard commercial version of the LM13700 can be powered from split supply rails of up to ±18V, or single-ended supplies of up to 36V. In use, I_D and I_{bias} should be limited to 2mA maximum, and the output current of each buffer stage should be limited to 20mA maximum.

VCA CIRCUITS

Figure 7 shows a practical voltage-controlled amplifier (VCA) made from half of an LM13700 IC. Here, the input signal is fed to the non-inverting terminal of the OTA via current-limiting resistor R4, and the high-impedance output of the OTA is loaded by R5, which determines the peak (overload) amplitude of the output signal in the way described last month. The output signal is made available to the outside world at a low-impedance level via the buffer stage, which is loaded via R6.

The Figure 7 circuit is powered from dual 9V supplies. The I_D current is fixed at about 0.8mA via R1, but I_{bias} is variable via R7 and an external gain control voltage. When the gain-control voltage is at the negative rail value of -9V, I_{bias} is zero and the circuit gives an overall 'gain' of -80dB. When the gain-control is at the positive rail value of +9V, I_{bias} is about 0.8mA, and the circuit gives a voltage gain of roughly x1.5. The voltage gain is fully variable within these two limits via the gain-control input. The two halves of the LM13700 have closely-matched characteristics, making the IC ideal for use in stereo amplifier applications. Figure 8 shows how two amplifiers of the Figure 7 type can be used together to make a voltage-controlled stereo amplifier. Note, in this case, that the I_{bias} gain-control pins of the two OTAs are shorted together and fed from a single gain-control voltage and current-limiting resistor. The close matching of the OTAs ensures that the gain-control currents divide equally between the two amplifiers.

Note that the Figure 7 and 8 circuits act as non-inverting amplifiers, since their input signals are fed to the non-inverting pins of the OTAs. They can be made to act as inverting amplifiers by simply feeding the input to the inverting pins of the OTAs.

The VCA circuit in Figure 7 can be used as an amplitude modulator or two-quadrant multiplier by feeding the carrier signal to the input terminal, and the modulation signal to the gain-control input terminal. If desired, the gain-control pin can be DC biased so that a carrier output is available with no AC input signal applied. Figure 9 shows a practical example of an inverting amplifier of this type. The AC modulation signal modulates the amplitude of the carrier output signal.

Figure 10 shows how half of an LM13700 can be used as a ring modulator or four-quadrant multiplier, in which zero carrier output is available when the modulation voltage is at zero (common supply rail) volts, but increases when the

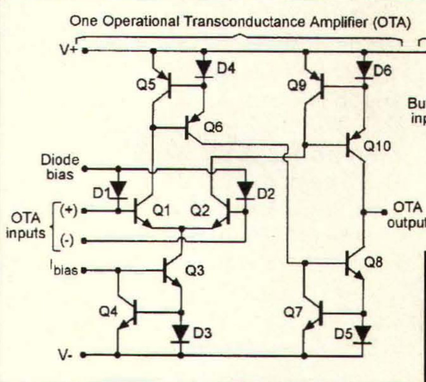


Figure 6. Internal circuit of half of the LM13700 dual OTA IC.

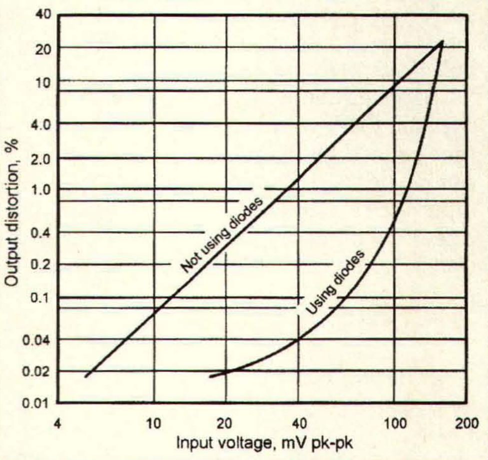


Figure 5. Typical distortion levels of the LM13700 OTA with and without the use of the linearizing diodes.

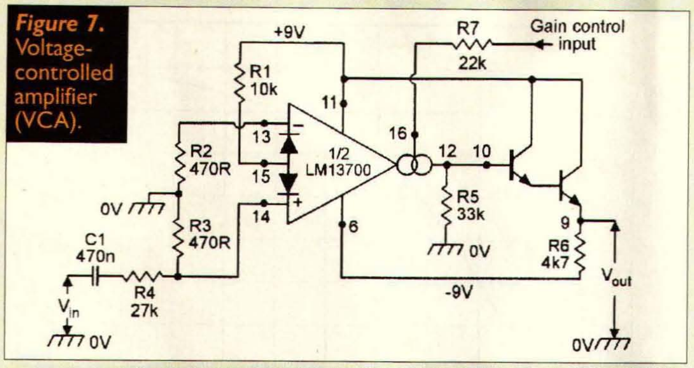


Figure 7. Voltage-controlled amplifier (VCA).

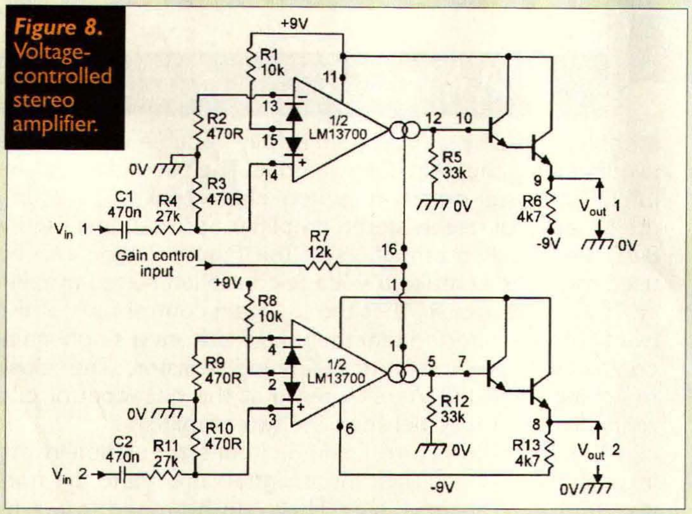


Figure 8. Voltage-controlled stereo amplifier.

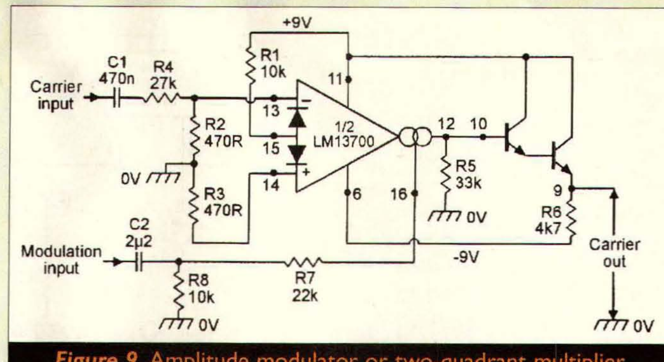


Figure 9. Amplitude modulator or two-quadrant multiplier.

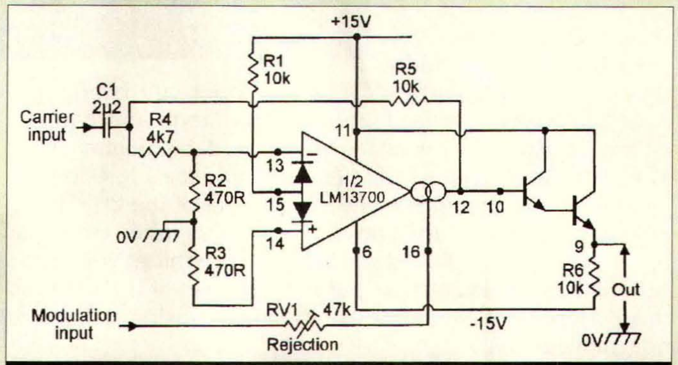


Figure 10. Ring modulator or four-quadrant multiplier.

modulation voltage moves positive or negative relative to zero. When the modulation voltage is positive, the carrier output signal is inverted relative to the carrier input, and when the modulation voltage is negative, the carrier is non-inverted.

The Figure 10 circuit is shown with values suitable for operation from dual 15V supplies, but is essentially similar to the Figure 9 circuit, except that R5 is connected between the input signal and the output of the OTA, and I_{bias} is "pre-settable" via RV1. The basic circuit action is such that the OTA feeds an inverted (relative to the input) signal current into the bottom of R5, and at the same time, the input signal feeds directly into the top of R5. RV1 is pre-set so that when the modulation input is tied to the zero volts common line, the overall gain of the OTA is such that its output current exactly balances (cancels) the direct-input current of R5, and under this condition, the circuit gives zero carrier output.

Consequently, when the modulation input goes positive, the OTA gain increases and its output signal exceeds that caused by the direct input into R5, so an inverted output carrier is generated. Conversely, when the modulation input goes negative, the OTA gain decreases and the direct signal of R5 exceeds the output of the OTA, and a non-inverted output signal is generated.

OFFSET BIASING

The circuits in Figures 7 to 10 are shown with OTA input biasing applied via 470R resistors wired between the two input terminals and the zero volts rail. In practice, this simple arrangement may cause the DC output level to shift slightly when the I_{bias} gain-control is varied from minimum value. If desired, this shifting can be eliminated by fitting the circuits with a pre-settable offset adjust control as shown in Figure 11, enabling the biasing resistance values to be varied slightly. To adjust the offset biasing, reduce I_{bias} to zero, note the DC level of the OTA output, then increase I_{bias} to maximum and adjust RV1 to give the same DC output level.

AN AUTOMATIC GAIN CONTROL AMPLIFIER

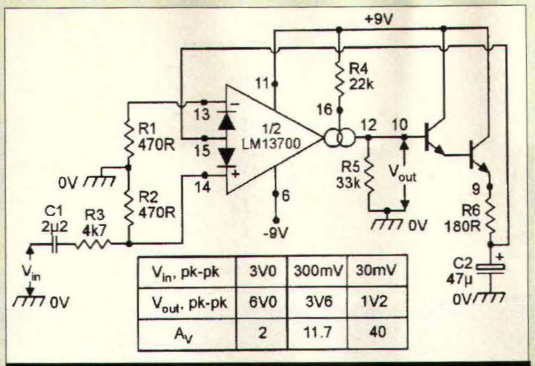
In the Figures 7 to 10 circuits, the amplifier gain is varied by altering the I_{bias} value. A feature of the LM13700, however, is that its gain can be varied by altering either the I_{bias} or the I_D current, and Figure 12 shows how the I_D variation can be used to make an automatic gain control (AGC) amplifier in which a 100:1 change in input signal amplitude causes only a 5:1 change in output amplitude.

In this circuit, I_{bias} is fixed by R4, and the output signal is taken directly from the OTA via R5. The output buffer is used as a signal rectifier — fed from the output of the OTA — and the rectified output is smoothed via R6-C2, and used to apply the ID current to the OTA's linearizing diodes. Note, however, that no significant ID current is generated until the OTA output reaches a high enough amplitude (3 x V_{be}, or about 1.8V peak) to turn on the Darlington buffer and the linearizing diodes, and that an increase in I_D reduces the OTA gain and — by negative feedback action — tends to hold V_{out} at that level.

The basic zero I_D gain of this amplifier is x40. Thus, with an input of 30mV peak-to-peak, the OTA output of 1.2V peak-to-peak is not enough to generate an I_D current, so the OTA operates at full gain. At 300mV input, however, the OTA output is enough to generate significant I_D current, and the circuit's negative feedback automatically reduces the output level to 3V6 peak-to-peak, giving an overall gain of x 11.7. With an input of 3V, the gain falls to x2, giving an output of 6V peak-to-peak. The circuit, thus, gives 20:1 signal compression over this range.

VOLTAGE-CONTROLLED RESISTORS

An unusual application of the LM13700 is as a voltage-controlled resistor (VCR), using the basic circuit in Figure 13. The basic theory here is quite simple – if an AC signal is applied to the R_x terminals, it will feed to the OTA's inverting terminal via C1 and the buffer stage and the R/RA attenuator, and the OTA will then generate an output current proportional to the V_{in} and I_{bias} values. Thus, since R = E/I, the circuit's R_x terminal acts like an AC resistor with a value determined by I_{bias}.



V_{in}, pk-pk	3V0	300mV	30mV
V_{out}, pk-pk	6V0	3V6	1V2
A_V	2	11.7	40

Figure 12. Circuit and performance table of an AGC amplifier.

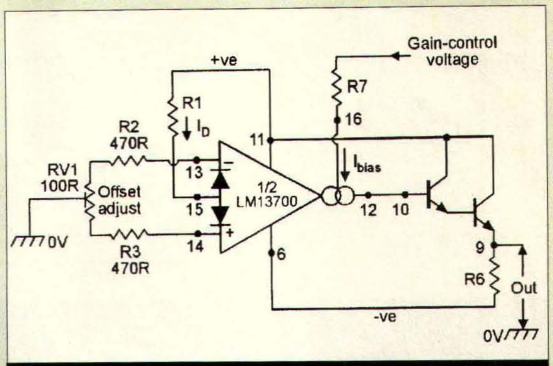


Figure 11. Method of applying offset biasing to the LM13700.

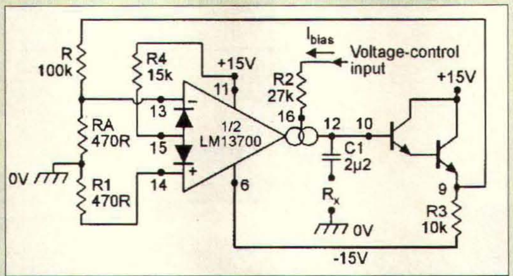


Figure 14. Voltage-controlled resistor with linearizing diodes.

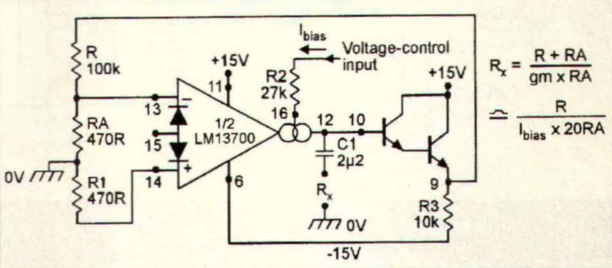


Figure 13. Voltage-controlled resistor, variable from 10k to 10M via I_{bias}.

The effective resistance value of the R_x terminal actually equals (R + RA)/(gm x RA), where gm is roughly 20 x I_{bias}. This formula approximates to $R_x = R/(I_{bias} \times 20RA)$, so, using the component values shown in the diagram, R_x equals roughly 10M at an I_{bias} value of 1μA, and 10k at an I_{bias} of 1mA. Figure 14 shows a similar version of the VCR, where the linearizing diodes are used to effectively improve the noise performance of the resistor, and Figure 15 shows how a pair of these circuits can be used to make a floating VCR in which the input voltage is direct-coupled and may be at any value within the output voltage range of the LM13700.

VOLTAGE-CONTROLLED FILTERS

An OTA acts basically as a voltage-controlled AC current source, in which an AC voltage is applied to the amplifier's input, and the magnitude of the output current depends on the value of I_{bias}. This fact can be used to implement a voltage-controlled low-pass filter by using half of an LM13700 in the configuration shown in Figure 16, in which the values of R, C, and I_{bias} control the cut-off frequency, f_o, of the filter. The operating theory of this circuit is as follows.

Assume, initially, that capacitor C is removed from the circuit. The input signal is applied to the OTA's non-inverting terminal via potential divider R1-R2, and the OTA's output is followed by the buffer stage and fed back to the inverting input via an identical divider made up of R and RA. The basic OTA thus acts as a non-inverting amplifier with a gain of R/RA but, since the input signal is fed to the OTA via a potential divider with a value equal to R/RA, the circuit acts overall as a unity-gain voltage follower.

Assume now that capacitor C is fit into place. At low frequencies, C has a very high impedance and the OTA output current is able to fully charge it, causing the circuit to act as a voltage follower in the way already described. As the frequency increases, however, the impedance (X) of C decreases and the OTA output current is no longer able to fully charge C, and the output signal starts to attenuate at a rate of 6dB per octave. The cut-off point of the circuit – at which the output falls by 3dB – occurs when $XC/20xI_{bias}$ equals R/RA, as implied by the formula in the diagram. With the component values shown, cut-off occurs at about 45Hz at an I_{bias} value of 1μA, and at 45kHz at an I_{bias} value of 1mA. A similar principle to the above can be used to make a voltage-controlled high-pass filter, as shown in Figure 17. This particular circuit has, with the values shown, cut-off frequencies of 6Hz and 6kHz at I_{bias} currents of 1μA and 1mA, respectively.

Numbers of filter stages can easily be cascaded to make multi-pole voltage-controlled filters. The excellent tracking of the two sections of the LM13700, make it possible to voltage-control these filters over several decades of frequency. Figure 18 shows the practical circuit of a two-pole (12dB per octave) Butterworth low-pass filter having cut-off frequencies of 60Hz and 60kHz at I_{bias} currents of 1μA and 1mA, respectively.

VOLTAGE CONTROLLED OSCILLATORS

To conclude this look at applications of the LM13700,

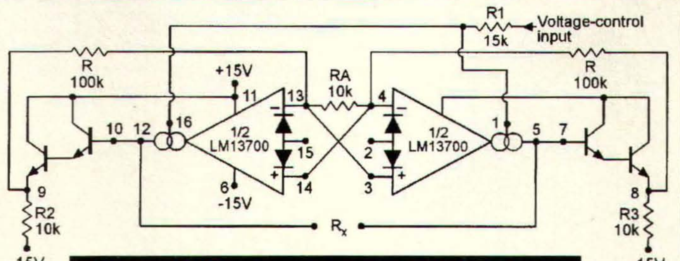


Figure 15. Floating voltage-controlled resistor.

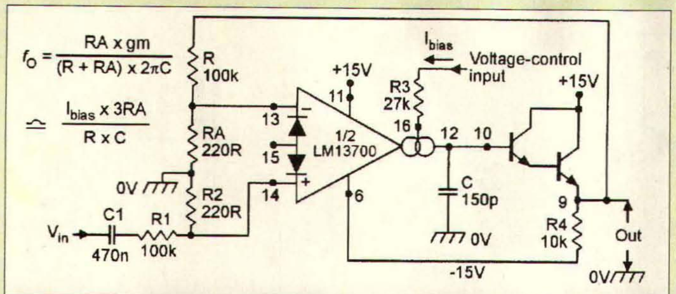


Figure 16. Voltage-controlled, low-pass filter covering 45Hz to 45kHz.

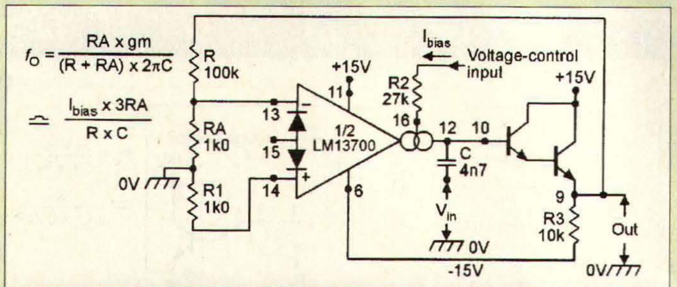


Figure 17. Voltage-controlled, high-pass filter covering 6Hz to 6kHz.

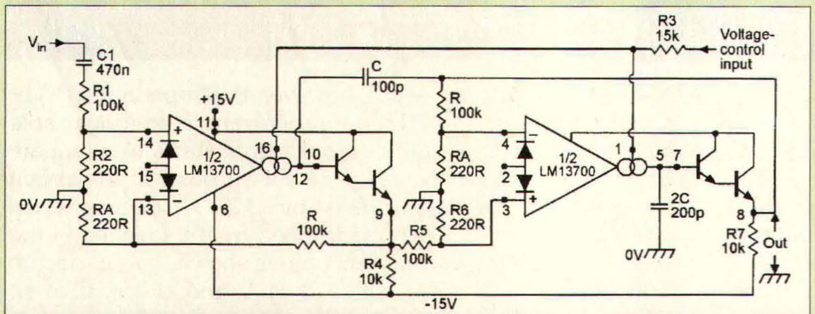


Figure 18. Voltage-controlled two-pole Butterworth low-pass filter covering 60Hz to 60kHz.

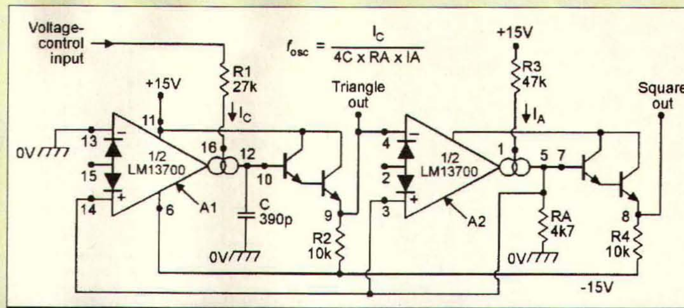
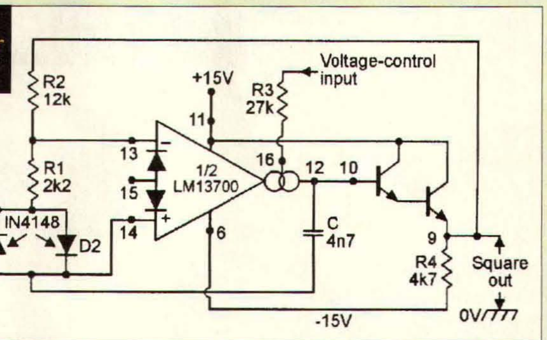


Figure 19. Triangle/squarewave VCO covering 200Hz to 200kHz.

Figure 20. Single-amplifier VCO.



Figures 19 and 20 show two ways of using the IC as a voltage-controlled oscillator (VCO). The Figure 19 circuit uses both halves of the LM13700, and simultaneously generates both triangle and squarewaves. The Figure 20 design uses only half of the IC, and generates squarewaves only.

To understand the operating theory of the Figure 19 circuit, assume initially that capacitor C is negatively charged and that the squarewave output signal has just switched high. Under this condition, a positive voltage is developed across RA and is fed to the non-inverting terminals of the two amplifiers, which are both wired in the voltage comparator modes.

This voltage makes amplifier A1 generate a positive output current equal to the bias current, I_C, and this flows into capacitor C, which generates a positive-going linear ramp voltage that is fed to the inverting terminal of A2 via the Darlington buffer stage until, eventually, this voltage equals that on the non-inverting terminal, at which point the output of A2 starts to swing negative. This initiates a regenerative switching action in which the squarewave output terminal switches abruptly negative.

Under this condition, a negative voltage is generated across resistor RA, causing amplifier A1 to generate a negative output current equal to I_C. This current causes capacitor C to discharge linearly until, eventually, its voltage falls to a value equal to that of RA, at which point the squarewave output switches high again. This process repeats *ad infinitum*, causing a triangle waveform to be generated on R2 and a squarewave output to be generated on R4.

The waveform frequency is variable via the voltage-control input, which controls the value of I_C. With the component values shown, the circuit generates a frequency of about 200Hz at an I_C current of 1μA and 200kHz at a current of 1mA.

Finally, Figure 20 shows a single-amplifier VCO circuit which generates a squarewave output only. The circuit operates in a similar manner to that described above, except that 'C' charges via D1 and discharges via D2, which generates a 'polarity' signal on the non-inverting terminal of the amplifier. **NV**

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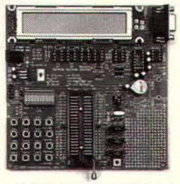

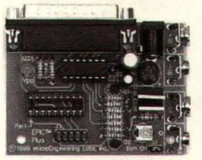

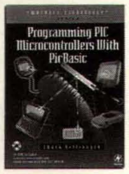

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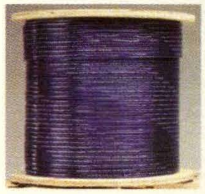

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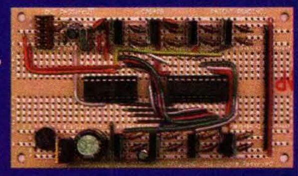

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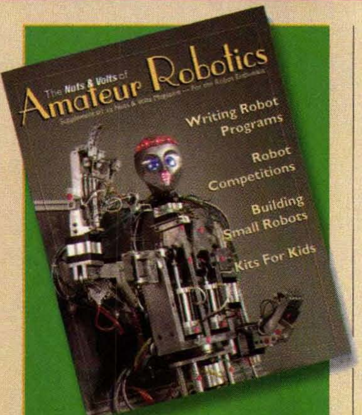

The **Nuts & Volts** of
Amateur Robotics
Supplement #2

Coming next month is our second supplement dealing with robotics for the hobbyist. Many of you will remember last August when we presented our first-ever robotics supplement. This second effort will be somewhat more technical and feature articles on:

- Building a Dual Motor Controller Board
- Metal Fabrication
- Using Two HC11s on One Robot
- Motion Control

as well as:

- Finding robot parts in unlikely, but everyday places
- The (RFL) Robot Fighting League
- The SOZBOT Story
- and much more

If you're a paid subscriber to *Nuts & Volts*, you will automatically receive the supplement with your June magazine. If not, you can pick it up on most newsstands or order it directly from us.

This robotics supplement will be the first of a planned quarterly printing. We also plan on producing additional supplements covering other subjects and would like to get input from our readers on topics to cover. Email your ideas to us and we'll take it from there. We've set up a special email address to send your input directly to our editorial planning department. Send your ideas to: **supplements@nutsvolts.com**

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Laser Insight

Produce Your Own Holograms With This Set-Up

Last month, we began a discussion on various hologram types and how they are produced. I concluded with a simple, steady platform on which a holographic set-up could be mounted. This month, we're going to take this idea a bit further and describe an experimental set-up you can make at home, and hopefully, produce some reasonably good holograms for yourself.

If the idea of making a hologram appeals to you, then you should like this article. If the idea seems daunting, fear not. You never know what you can do until you try. This set-up will be kept as simple as possible, with no precision mounting schemes like those used in optical labs. We'll use wax, putty, hot-melt glue, or screws to assemble the parts on the table — nothing elaborate. I know that most people have to work with a tight budget — including myself — so I like to keep things as simple as possible, and hopefully without sacrificing too much.

Stability of the set-up

The three words that determine the selling potential of a piece of real estate are location, location, location. I'm sure you've heard that many times. When it comes to making a hologram, the three words that come to mind are stability, stability, stability. The stability not only refers to the table, object, and optical mounts, but also to the laser used for exposure.

A HeNe laser can be used for exposing the film, but care should be taken to eliminate any vibration on the laser, and any drafts that could affect the temperature of the HeNe. Before exposing a film, the laser should be turned on for at least one hour to allow the temperature of the laser to stabilize.

You'll notice in the drawings that the HeNe laser is mounted to a fairly massive stand. The stand provides two important functions: it offers good mechanical stability and good thermal stability. A change in the temperature of the laser during exposure will cause a very small change in the distance between the mirrors of the HeNe. The mirrors act as an interferometer themselves, and will have an effect on the longitudinal mode structure of the beam.

A shutter can be as simple as a card held in front of the laser until the exposure is made, provided any scattering or reflections from the card are absorbed before they can reach the film. Any type of shutter that introduces vibration should be avoided. For this reason, it is recommended that the laser be mounted on a separate platform from the rest of the optical components. If you use a mechanical shutter to open the laser beam to the table, then you should mount the shutter on a separate stand from the laser and the optical table.

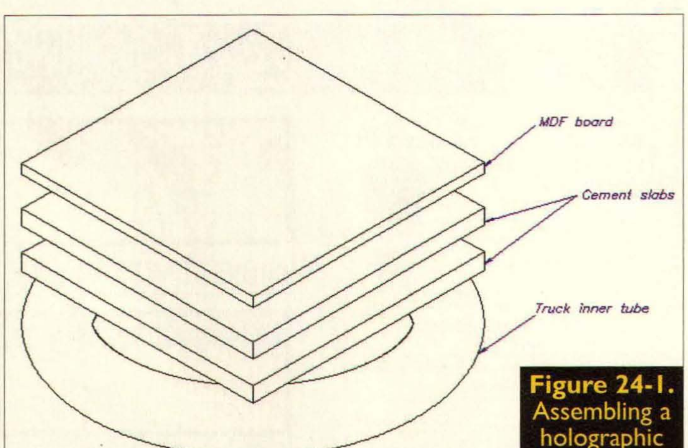


Figure 24-1. Assembling a holographic table.

The problems of mechanical and thermal stability are not so serious when a pulsed laser source is used for the exposure, and we will be building a pulsed laser in a forthcoming issue. Pulsed lasers are used to record dynamic changes that take place when machines are in operation or otherwise stressed. Such applications include stress testing of jet engine components, turbine blades, gun barrel deformation, etc. This type of set-up usually requires other, advanced peripheral equipment, plus additional optical components we haven't covered yet, so we'll save this for another issue.

When assembling the optical table, remember too, that the film must also be held rigidly, yet must be easy to put into place and removed in the dark.

Laser beam purity

During the discussion last month, I mentioned a few other things that are important when making holograms. Among them were film resolution and the coherence length of the laser. The film resolution refers to the resolving power of the film used to record a hologram, and will have a direct effect on the quality of the hologram produced.

Most holographic film has a resolution of several thousand lines per millimeter, where 'normal' 35mm film may have a resolution of only a couple hundred lines per millimeter. The coherence length of the laser affects the spatial clarity of the hologram, the depth, if you like, to which you can see into the picture. It affects the depth of focus and therefore the clarity of foreground and background information surrounding the object being photographed.

With a poor coherence length, details on either side of the focal plane will be lost, and the hologram will look fuzzy and unclear. With a long coherence length, details will be sharp and a greater amount of information will be recorded, resulting in a sharp, clear hologram.

I mentioned that the coherence length depends on how cleanly the laser produces a single wavelength. Most lasers do not produce a single, pure wavelength, but instead produce a narrow band of wavelengths surrounding the principle wavelength. The bandwidth (or linewidth, as it is usually called) of a typical HeNe laser is very small, and thus, produces a coherence length of about 50cm or so, which is more than enough for our simple set-up.

Most HeNe lasers these days also produce a beam that has a very good spatial profile. That is, the laser shows a very near Gaussian energy distribution across the diameter of the beam, which is important in holography. The closer the beam is to Gaussian, the closer the wave fronts are to being of uniform, in-phase distribution.

If you intend to use an older laser, or perhaps a HeNe laser you made yourself, you may need to pass the beam through a pinhole filter to clean up the beam before it gets onto the optical table. To do this, I would suggest getting a spatial filter (pinhole) assembly from Edmund Scientific. These kits come complete with filter and mounting hardware, and instructions on how to set it all up.

The spatial filter removes some of the higher-order spatial modes, leaving the remaining beam closer to a single order mode (TEM00 mode or Gaussian distribution). The pinhole kits are not cheap though, especially if you buy multiple pinholes, so I suggest you speak with one of the technical staff before you decide to buy. It may be less expensive than buying a new laser. As I mentioned in a previous column, using a pinhole filter such as this will slightly reduce the useable power output from the laser, so you will need to adjust the exposure if you include this filter assembly.

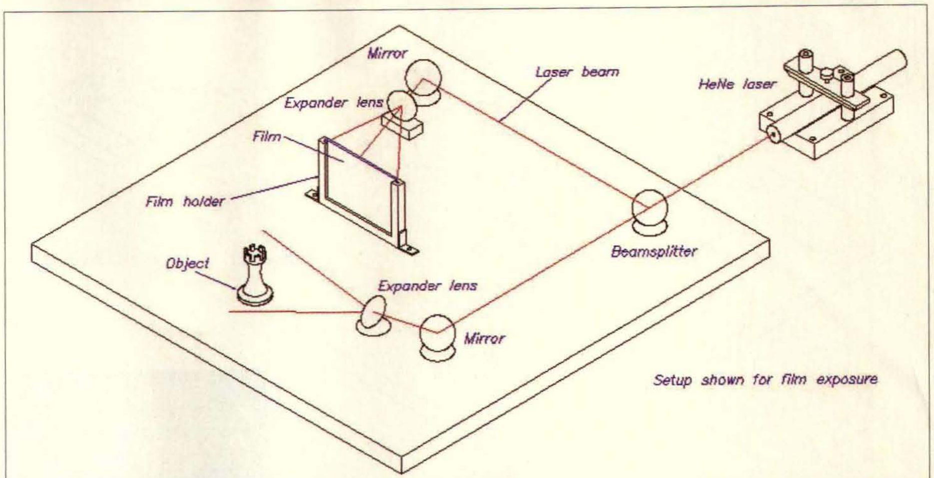


Figure 24-2. Assembling the components on the MDF tabletop for a reflection-type hologram.

For making holograms, I suggest that you use a HeNe rather than a laser diode. Typical HeNe lasers these days are very stable, and have a good spatial and temporal profile. A diode laser is not a good choice for holography. The mode structure is not good, and the divergence, typically, is very bad when compared to a HeNe laser of the same power output.

Longitudinal mode elimination

One problem that may show its ugly head has to do with longitudinal modes. If there are too many modes operating, the hologram will appear fuzzy and unclear, despite being on a stable platform. There will also be little depth information. Longitudinal modes were discussed some time back when the mode structure of a laser beam was the topic. Look through the Jul. 2001 issue of *Nuts & Volts*. Longitudinal modes in a CW laser are not easy to detect, and so it is difficult to know when their numbers have been reduced. It is mainly by trial and error, using interferometric techniques, that these extraneous modes can be detected and eliminated. However, if you use a low-order mode HeNe laser, you should not have a problem with these modes.

In a pulsed laser, the situation is a little different, and if you were successful in building a high-speed photodetector, as described in this column in the Jan. 2003 issue, I will be describing a method whereby you can use the detector to see these modes. I will also suggest a way of reducing their numbers using another type of interferometer. However, I will cover this in a future issue, so stay tuned.

A word on the optics

When choosing the optical components, use lenses that have an AR coating on both sides. Usually, a single-layer magnesium fluoride (MgF_2) coating is applied to all optics for use in the visible spectrum. This will cut down on the number of extraneous reflections that would otherwise impede our experiment.

For the same reasons, use first surface mirrors to redirect the laser beam. Having a second surface reflection will produce a second (though weaker) set of interference fringes that will interfere with the wanted image by producing ghost images.

The optical table and set-up

The table described in last month's column should offer good stability for our first holograms. The cement slab combination has good mass properties, and is not affected by temperature variations. The truck inner tube offers vibration isolation from ground-borne noise (from traffic, etc.). Finally, the MDF top provides a flat surface for easy mounting of the various optical components. Figure

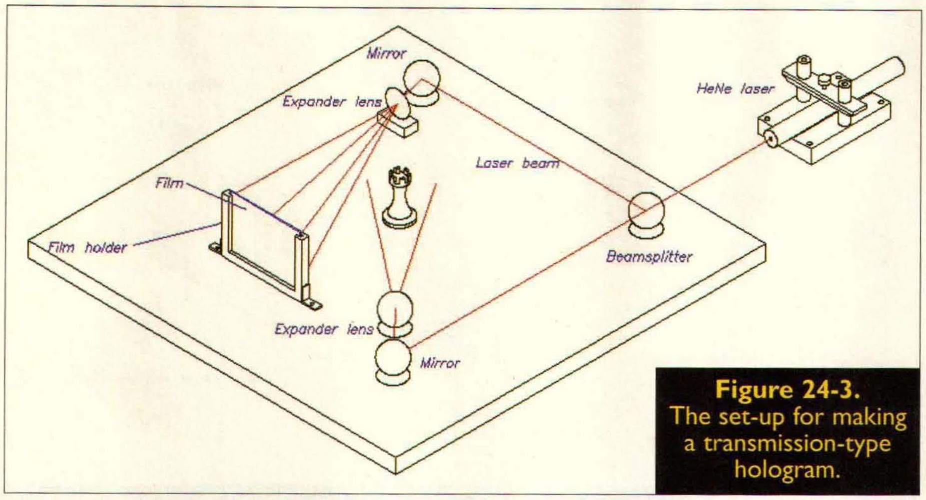


Figure 24-3. The set-up for making a transmission-type hologram.

24-1 shows the assembly of the optical table. Figure 24-2 shows how simple the optical set-up can be made.

This arrangement will produce a reflection-type hologram. The film plane mount is screwed down to the MDF board to provide a rigid mount to which the film is attached. I show a grooved upright assembly, but you can use almost anything to hold the film vertically. You just need to be able to register it correctly when you replay the developed hologram. The lenses and mirrors can be attached to the MDF board using wooden blocks and candle wax, putty or modeling clay, or hot-melt glue. The use of these materials will allow easy repositioning for experimentation.

To avoid moving anything during exposure, use a piece of card to block the HeNe beam path while getting everything else prepared. As I said before, it is vital that nothing moves during the exposure of the film to the HeNe beam, and a piece of card is easily and quickly removed and replaced without disturbing anything.

I suggest mounting the HeNe on a separate table, making sure it is rigidly fixed, and that you can remove and insert a piece of card in front of the laser to serve as the shutter. When the card is in place, it must be prevented from falling or being disturbed while all table vibrations are settling. Figure 24-3 shows the optical arrangement for producing a transmission-type hologram.

Exposing the film

Choose your subjects carefully. Don't use objects that have very fine details until you get skilled in estimating the illumination and exposure time accurately. Don't use live animals. Chess pieces, children's number/letter blocks, and models cars and airplanes can be very forgiving objects to practice on. By themselves, they may not excite you too much, but in a hologram, they can be quite spectacular.

Whichever type of hologram you experiment with, start by getting the laser illumination right. The alignment of the object and reference beams can be done quite easily by replacing the film with a piece of white card. Put a block in front of the reference beam and allow the scattered light from the object to fall onto the card. The illumination should be as uniform as possible over the surface of the card.

Next, block the object beam and allow the reference beam to fall onto the card. Again, it should be uniform, but this time it should also be much brighter. Approximately 10 percent of the total beam power should be in the object beam, the remaining 90 percent serves as the reference beam. These are the approximate proportions of object beam to reference beam. There are no magical numbers that will give a perfect exposure, so you may need to experiment a little with the beam-splitter ratio.

While you are setting things up and adjusting the optics, there will be some vibrations introduced into the assembly. These vibrations should be given time to subside before any exposure is made. As I mentioned before, a movement of only a half wavelength can destroy a hologram! For safety, allow the HeNe to warm up for at least an hour or so before you make adjustments to the rest of the optical set-up.

When you have things where they need to be, and the HeNe beams are going in the right directions, block the HeNe beam with a card while you mount the film. After the film is mounted, allow a further couple of minutes for the small vibrations in the table to die down. You obviously have to do the film mounting part of this operation in the dark, so take care not to let any stray light from the HeNe leak onto the film during this critical stage. Safelights are not an option.

You'll have to experiment with your set-up before the correct exposure time can be determined. The power output of the HeNe at various points around the set-up can only be estimated, depending on your optical

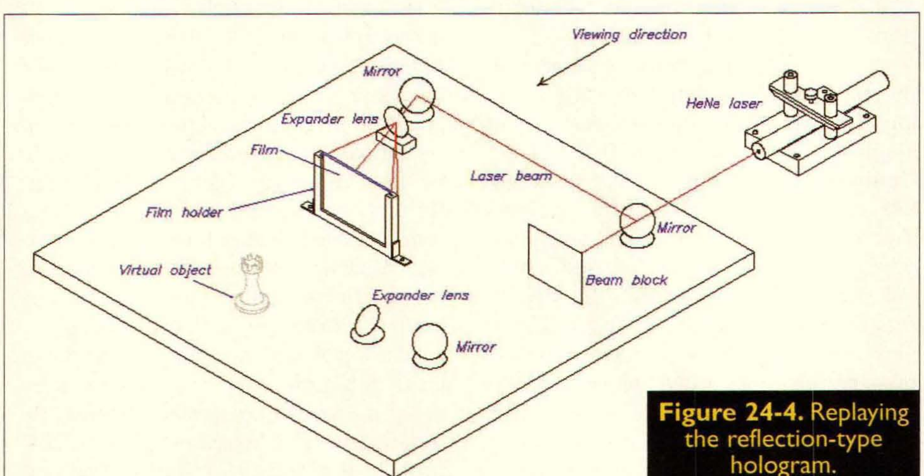


Figure 24-4. Replaying the reflection-type hologram.

Table 1. Holographic Film Selection Guide.

Kodak Product	Sensitivity at 6328	Resolution	Relative Contrast	Development
649-F plate or film	900	2000+	5/4	6-8 minutes D19
120 (02 or 01) film	400	2000+	5/4	"
125 (01 or 01) film	—	1200+	4	"
High speed 131 film	5-8	1200+	7	"
Technical Pan 2415	0.4	320	1-3	"

components, and so there may be quite a variation from your set-up to the next guys'. If you are familiar with normal photographic techniques, then you should know how to make a test strip, exposing sections of film in one-second intervals. With care, this can be done quite effectively.

From here, you can usually estimate how long an exposure is required to get the right exposure. You will waste a plate or perhaps two or three while getting the correct exposure and development time, but subsequent exposures will be right.

Developing the hologram

Again, if you are familiar with photographic techniques, you probably already know how to develop film, so I'm not going to dwell on it here. Use the recommended developer, following the instructions for the film type you have. When developing the image, resist the temptation to overdevelop. There will not be an image to judge, so again, there is some trial and error to determine the correct development time.

As a guide, Table 1 compares a number of different films and developing parameters. The film types listed here are for general holographic use, and are sensitive in the red region, and, thus, usable with a common red HeNe.

While writing this article, I contacted Kodak, and they told me that holographic film is no longer available from them. However, there are a number of Kodak Professional Authorized Dealers that still have Kodak High Speed Holographic film #SO-253.

The suggested list price for the High Speed Holographic Film/SO-253, catalog #177-2672, is $77.35 for a 25-sheet box.

If you visit the Kodak website at **www.kodak.com/go/proproducts network**, there are in-depth articles on the various film types produced. You can also search for a dealer near you using specific criteria such as Zip Code, Area Code, Dealer Name, City, or State.

I am indebted to one of the regular readers of this column who contacted me some time ago regarding the subject of holography. His name is Jack Mills, from Ben Lomond, CA. He has done work of his own in this field. Jack has given me some valuable information that I want to pass on to all readers of this column. He was experimenting with black-and-white Litho film (some types of which are insensitive to red light, and can therefore be processed in a darkroom environment using a red safelight) and found that some of these may be usable for holographic purposes. The film listed below is one that can be exposed using a green HeNe laser while using a red safelight. Jack recommends using a diluted paper or film developer with this film, as it will result in a finer grain structure. The film is a lot cheaper than the Kodak variety. The material is standard 35mm film #520-100 and is available from: Freestyle Camera, Inc., 5124 Sunset Blvd., Hollywood, CA 90027. The price in the 2001 catalog is $27.95/100 ft. roll. Their toll-free phone number is (800) 292-6137. You may also check out their web page at **www.freestyle camera.com**.

Jack sent me a couple of samples of what he had made and it looks quite promising.

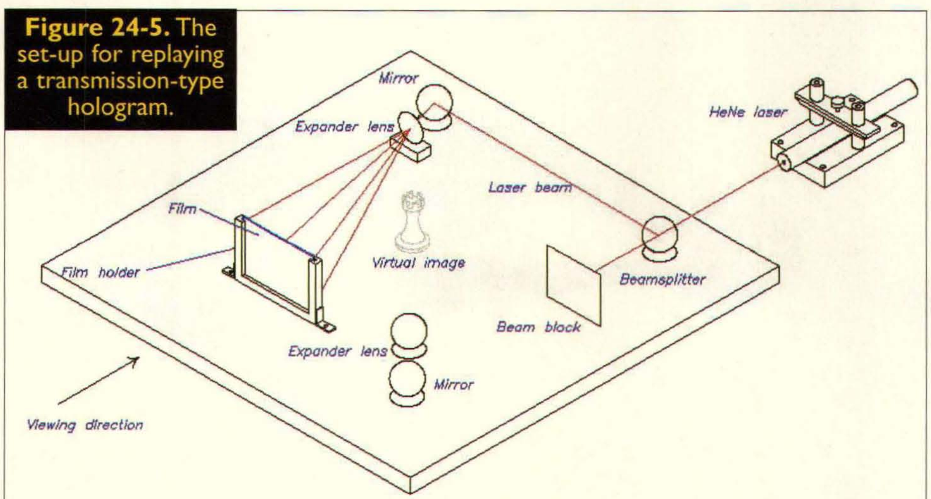


Figure 24-5. The set-up for replaying a transmission-type hologram.

Playing back the hologram

Playing back the developed hologram is done by almost the same method used to expose the film. The developed film is placed in the film holder, in the same orientation that it was during exposure. This is an important point, because if the film is in a different orientation, you won't see quite what you expect. So, make sure the film is in the holder in the same position. Turn on the HeNe laser, and put a block in the object beam path as shown in the drawings, but allow the reference beam to go through. Place yourself in the right position to view the hologram and see what you get.

If the image is dull or dark, you may need to adjust your exposure/development time. If you get only a partial image, or none at all, the chances are that something moved during the exposure stage. Figure 24-4 shows the set-up for replaying a developed reflection-type hologram, while Figure 24-5 shows the set-up for replaying a transmission-type hologram.

Good luck with this experiment. Let me know how you fare with your set-up. If you have any ideas to improve this without a huge bundle of money being involved, share your ideas with us.

If you have questions, or ideas for future columns, you may contact me as always at **stanley.york@att.net**, or through this magazine. As always, it sometimes takes me a while to answer all my emails, but I always reply. **NV**

Understanding, Designing, and Constructing Robots & Robotic Systems

Amateur Robotics

If one is good, more is better ... microcontrollers, that is ...

Embedded microcontrollers are great building blocks because everything is built-in. But when you need more tools, you need more embedded microcontrollers. This article shows how easily multiple controllers can be made to work together. A working example of a fast inter-processor serial communication bus shows how to string as many controllers together as necessary and communicate at over 50K baud. In addition, this article shows how to generate three PWM signals from a lowly AT90S2313, which has no PWM hardware on board.

All of the code in this article is written in RVK-Basic, a Basic compiler, which is free for personal use and can be downloaded from either **www.nutsvolts.com** or **www.rvkbob.com**. The chief feature of RVK-Basic is its blazing speed. Using most of the Atmel AVR microcontrollers (**www.atmel.com**) and RVK-Basic, you really can execute millions of lines of Basic code per second.

The Problem: Insufficient PWM

We wanted to build a simple robot for a school in Tucson, AZ, to use to teach youngsters how to write programs in Basic that really make things happen. The simplest solution was to use a servo-controller to drive each of two wheels and a third servo to position a weapon. The servos on the drive wheels would be hacked to provide velocity control instead of position control. Thus, each function could be controlled by a standard servo PWM signal (described in detail later). The problem was that the available microcontroller had no more than two independent PWM outputs available. In order to get three PWM channels, it was necessary to add at least one more microcontroller. But how could we get one micro to talk efficiently and easily to the other?

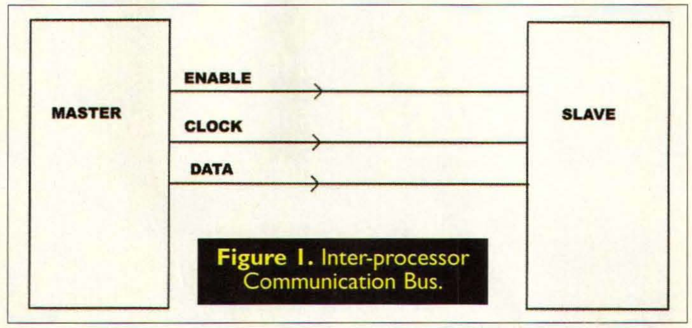


Figure 1. Inter-processor Communication Bus.

Communications Over SPI Between Micros

The AVR processors are readily programmed over a Serial Peripheral Interface (SPI), but there is no generally usable SPI interface available for other tasks. This I solved in a simple, elegant manner.

SPI requires (at a minimum) a data line, a clock line, and preferably some kind of line to synchronize the serial transmission of data. When programming the microcontroller, the reset pin to the chip is used to enable programming. I settled on a three-wire interface, clock, data, and enable, which would guarantee synchronization and also allow the easy addition of a third (or more) processor(s), should the need ever arise, while minimizing the number of pins used on each processor. The hardware interface is shown in Figure 1.

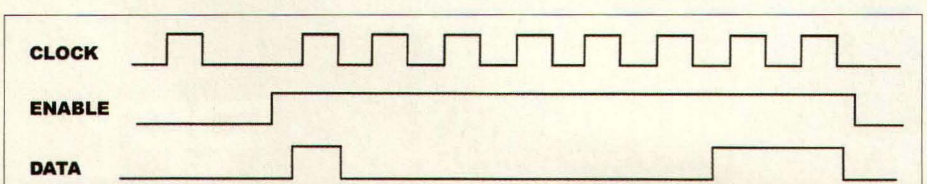


Figure 2. An Eight-bit Data Transfer.

In this example, all of the interface pins on the Master controller are outputs and all are inputs on the Slave controller. A third processor could be added by simply connecting the clock and data from the Master and by generating a separate ENABLE from the Master to the third microcontroller. If bi-directional data flow was ever needed, I would recommend a separate data line, which would always be an input to the Master. I haven't written code for this type of communication (because I haven't needed it yet), but if any reader would like to develop bi-directional data transfer in RVK-Basic, I would love to see a copy of it (**rvkbob@att.net**).

The clock line must be connected to the INTERRUPT 0 pin of the Slave. The Slave is interrupt-driven by the clock line. When each clock pulse arrives, the Slave reads the enable line and data line and takes appropriate action.

Figure 2 shows how eight bits of data could be transferred over an SPI bus. The first clock pulse, when the enable is low, is used by the Slave to reset its internal bit counter, guaranteeing synchronization on every transfer. The Most Significant Bit is transferred first, so the example above shows a data transfer of &H83.

For actual use in our robot, I have set all data transfers to be 16 bits long. The first byte is treated as the address of the command channel and the second byte is the data for that channel. When all 16 bits have been received, a message-ready flag is set, which informs the main program to read the data in the incoming message buffer.

The code that actually runs in the Slave processor follows. Note the INT0 interrupt handler at the bottom of the program. This is the routine that performs the interface to the SPI bus. Whenever a two-byte message is ready in the array msg@[], the variable msgrdy is set to a non-zero value. The message handler in the MAIN DO loop reacts to this and transfers the data to the proper PWM channel.

The remainder of the code in the MAIN loop synthesizes three servo PWM outputs. The output pulse width varies from 1.2 to 1.8 milliseconds in proportion to the commanded value and repeats the pulse about every 40 milliseconds.

```
DEVICE 2313
     MHZ    8

     REVISION 021225.0 3 channel pwm
     controller

     '___________________________
     '-    Controls 3 channels of pwm for rc -
     '-    servo controllers.              -
     '-    Input is via SPI:               -
     '-    SPI command format is           -
     '-    ch# (msg@[0]): command
     '-    (msg@[1]  -
     '-                                    -
     '-    The output duration is proportional
     '-    to  -
     '-    the input command: varying from
     '-    1.20   -
     '-    to 1.80 msec for commands of 1 to
     '-     200.  -
     '___________________________

     DIM msg@[5]

     DIRPORT D,&B01111010
     EQU "D,6","CH0"
     EQU "D,5","CH1"
     EQU "D,4","CH2"
     EQU "D,2","SPICLK"
     '..NOTE: "SPICLK" must be on
      INTERRUPT 0 pin..

     DIRPORT B,&B00111111
     EQU "B,7","SPINBL"
     EQU "B,6","SPIDATA"

START:

     msgcnt = 0
     msgrdy = 0
     '..the following is the interrupt for
     interprocessor communications
     INTERRUPT 0, DOWN

     ch0 = 100          '..0 rpm or mid position
     ch1 = 100          '..0 rpm or mid position
     ch2 = 100          '..mid postion for spear

MAIN:  DO

       '....This is the MESSAGE HANDLER
       that reads the message buffer.
     IF msgrdy | 0 THEN
       chnum = msg@[0] AND &H03
       msgval = msg@[1]
       msgrdy = 0

       BEGIN CASE chnum
         CASE 0
           ch0 = msgval
         CASE 1
           ch1 = msgval
         CASE 2
           ch2 = msgval
       END CASE
     END IF
     '....END of MESSAGE HANDLER.....


     INCR cycctr
     IF cycctr > 39 then
       cycctr = 0

          '..minimum on time is 1.20 msec...
       SETBIT "CH0"
       SETBIT "CH1"
       SETBIT "CH2"
       PAUSE 1.194
```

```
        '..This generates the PWM outputs.
        '..ON duration depends on ch#.....
      FOR pwmctr = 1 to 200
        IF ch0 > pwmctr THEN
          SETBIT "CH0"
        ELSE
          CLRBIT "CH0"
        END IF

        IF ch1 > pwmctr THEN
          SETBIT "CH1"
        ELSE
          CLRBIT "CH1"
        END IF

        IF ch2 > pwmctr THEN
          SETBIT "CH2"
        ELSE
          CLRBIT "CH2"
        END IF
      NEXT

    ELSE
      CLRBIT "CH0"
      CLRBIT "CH1"
      CLRBIT "CH2"
      PAUSE .5
    END IF
  LOOP

'=====BEGIN INTERRUPT HANDLERS======

'======BEGIN INT0 HANDLER============
'=  inputs: "SPINBL","SPIDATA","SPICLK"   =
'=  output: msgrdy, msg@[]                =
'=  uses: int01, int02, int03             =
'=  receives two bytes over SPI, msb first.  =
'=  puts result into msg@[0] (first byte) and =
'=  into msg@[1] (second byte).           =
'=======================================
INTERRUPT 0
      PUSHREG
      PUSHFLAGS
      INBIT int01,"SPINBL"
      IF int01 = 0 THEN
        msgrdy = 0        '..message ready
flag...
        int03 = 0           '..bit counter..
      ELSE
        SHIFT int02,1,LEFT
        INBIT int01,"SPIDATA"
        IF int01 | 0 then
          int02 = int02 OR 1
        END IF
        INCR int03
        BEGIN CASE int03
          CASE 8
            msg@[0] = int02
          CASE 16
            msg@[1] = int02
            msgrdy = 1
        END CASE
      END IF
      POPFLAGS
      POPREG
END INTERRUPT
'======END INT0 HANDLER==============

'=====END INTERRUPT HANDLERS========
```

The Code for the Master Controller

The Master controller code is written to allow a novice to just drop his own code into the main loop and be up and running. Comments identify where I have included example code, which, in this example, just aimlessly varies the commands to each of the three PWM channels once per second. The example code should be replaced by your code.

The SPIOUT routine is the code that actually transfers any command over the SPI bus to the Slave.

```
DEVICE 8535
      MHZ    8

      REVISION 021225.0-rvk MASTER
      CONTROLLER

      DIRPORT C,&B11110000
      OUTPORT C,&B00001111
      EQU "C,6","SPINBL"
      EQU "C,5","SPIDATA"
      EQU "C,4","SPICLK"
```

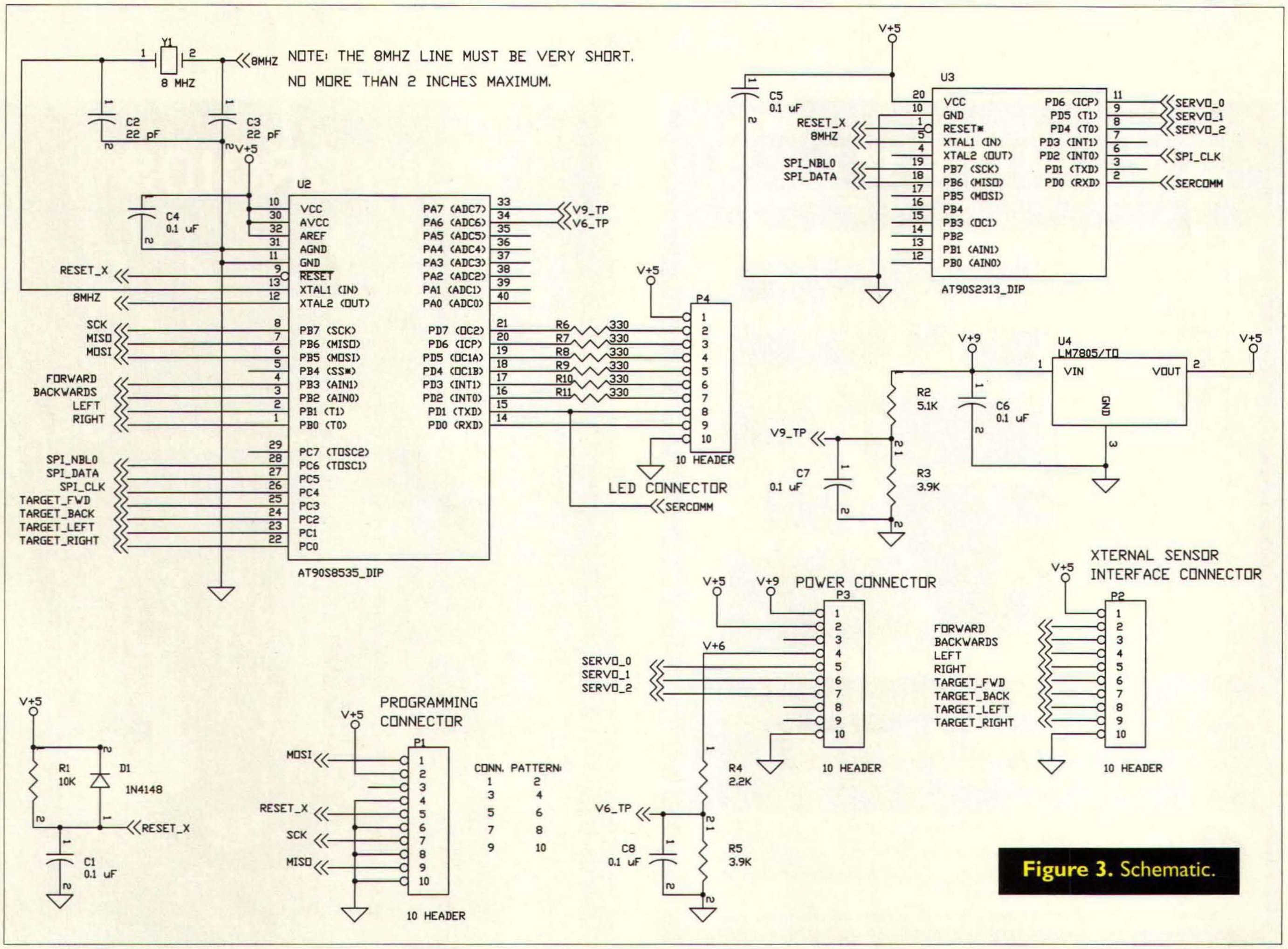


Figure 3. Schematic.

```
    msg% = 0
    wcmd = 100        '..wheel command
   (stopped)
    scmd = 0          '..spear command
   (retracted)

MAIN:  DO

'=========================================
           '=Place user code inside this DO
           '=LOOP. =
           '=Read the BLK sensors for
           '=blockages.  =
           '=Read the TGT sensors for
           '=targets.=

'=========================================
           '=To control servos, send msg% out
           '=via =
           '=routine SPIOUT. Do not call
           '=SPIOUT   =
           '=more than once every 2 msec.   =
           '=Format of msg% is: servo # in
           '=upper  =
           '=byte with command in lower
           '=byte.    =
           '= Channel 0 is left wheel.        =
           '= Channel 1 is right wheel.       =
           '= 0 means full reverse, 50 is half =
           '= reverse, 100 means stop, 150 is=
           '= half speed forward,             =
           '= 200 means full forward.         =
           '= Channel 2 is the robot's spear. =
           '= 0 means retracted, 200
           '=extended.   =
'=========================================

     '...BEGIN EXAMPLE CODE...

'...code in this block should be deleted
'...and replaced
'...by the user's code..............................

'This will issue forward, stop, & reverse
'commands each second..
IF wcmd = 200 THEN
  wcmd = 0
ELSE
  wcmd = wcmd + 100
END IF
msg% = wcmd
GOSUB SPIOUT
PAUSE 10      '..allow slave to settle
msg% = &H100 + wcmd
GOSUB SPIOUT
PAUSE 10      '..allow slave to settle

'This will change the position of the
'spear each second...
IF scmd = 0 THEN
  scmd = 200
ELSE
  scmd = 0
END
msg% = &H200 + scmd
GOSUB SPIOUT

PAUSE 0.98
'...END EXAMPLE CODE.....
LOOP

'======BEGIN SUBROUTINES============

'======BEGIN SPIOUT===================
'=   INPUT: msg%                                   =
'=   OUTPUT: "SPIDATA","SPICLK","SPINBL" =
'=   uses: spi00~,spi01%,msg%                      =
```

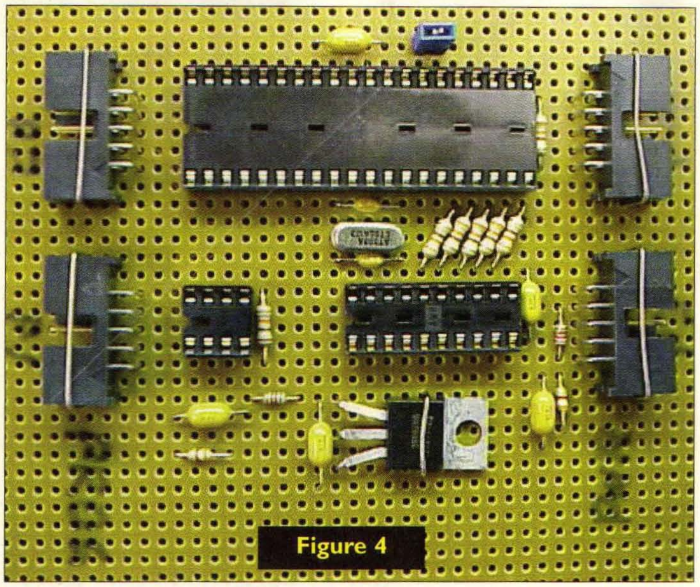



Figure 4

```
'=      Transmits msg% (hi byte first, hi bit first)    =
'=      out over SPI. A message is transmitted in       =
'=      about 256 usec.                                 =
'=      The receiving device must be able to handle an  =
'=      interrupt in no more than 15 usec.              =
'=======================================================
        STACK 2
SPIOUT: CLRBIT "SPINBL"
        CLRBIT "SPICLK"
        GOSUB TK5U
        SETBIT "SPICLK"          '..reset the interface..
        GOSUB TK5U
        CLRBIT "SPICLK"
        GOSUB TK5U
        SETBIT "SPINBL"
        FOR spi00~ = 1 TO 16
          spi01% = msg% AND &H8000
          IF spi01% | 0 THEN
            SETBIT "SPIDATA"
          ELSE
            CLRBIT "SPIDATA"
          END IF
          GOSUB TK5U
          SETBIT "SPICLK"
          GOSUB TK5U
          CLRBIT "SPICLK"
          GOSUB TK5U
          SHIFT msg%,1,LEFT
        NEXT
        CLRBIT "SPINBL"
RETURN
'======END SPIOUT========================================


'======BEGIN TK5U========================================
'=======================================================
        STACK 2
TK5U:   PAUSE .004
RETURN
'======END TK5U==========================================
'======END SBROUTINES====================================
```

As can be seen in the SPIOUT routine, we're transferring data at about 15 microseconds per bit. So 16 bits of data (including the synchronization bit) require about 255 microseconds. That's an average transfer rate of 62,745 bits per second, a respectable and useful rate. If this were implemented on a 16 MHz processor, like the MEGA8, the data rate would go up to 125 Kbaud. Not at all bad for cheap Slaves where the interface is handled in the background by an interrupt handler!

Schematic of the Robot

A schematic of the robot is shown in Figure 3. The only necessary interconnections between the two processors are the three SPI wires, although in this design, I did include a UART connection (just in case I had trouble making the SPI bus work). As it turned out, the UART connection was totally unnecessary.

The Completed Board

The robot's controllers (there were two systems built) were built up on perf-board. See Figure 4.

The 40-pin socket is for the 8535 Master controller and the 20-pin is for the 2313 Slave. The back side of the board is shown in Figure 5.

As you can see, it isn't at all necessary to lay out a printed circuit board if you wire neatly. So even a multiple-processor job can be reasonably built up on perf-board.

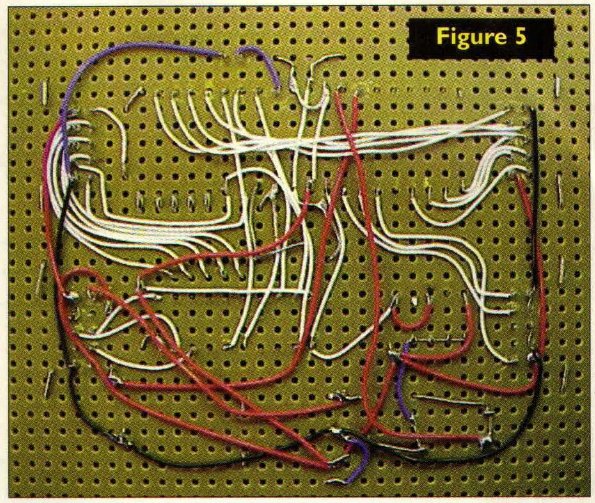


Figure 5

An Improved Design

As you can see, I implemented the Slave with a 2313 processor. It could be done with a 1200 also. I originally chose the 2313 because it had a UART on board which I could use for communications if the SPI bus did not work. Because I had a 2313 with RAM on board, I put the message buffer in RAM.

This was not necessary at all. The buffer could have been implemented in two simple variables, perhaps msg0 and msg1. Then the entire Slave processor would have been the ultra-cheap, bottom-of-the-line processor, the AT90S1200. It's amazing what can be done with very little.

The Master controller was chosen to be an 8535 because we wanted the students to have lots of room for code. A smaller processor would certainly work here, depending on what you actually need. **NV**

by Jon Williams

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

Stamp Applications

Keyboard Entry and Display

I'm sure you've heard, perhaps many times, that "Imitation is the sincerest form of flattery." I happen to agree with that assertion. What I've also found is that imitation is an excellent opportunity for self-education. Let me explain.

I've been very fortunate in my career to be asked to provide training for those interested in learning what I happen to know. For the last couple of years, I've been employed by Parallax and have had the opportunity to teach many people (mostly teachers) how to program and use BASIC Stamps. I am often asked what steps one can take to learn to program BASIC Stamps, and I generally list three things:

1. Study the available documentation and examples.
2. Solve a problem — yours or someone else's.
3. Attempt to duplicate an existing device.

Of course, for the purposes of this month's article, we're going to focus on suggestion #3.

The reason, honestly, has to do with a recent training session I conducted in the city of Utrecht, located in western Holland, not too far from Amsterdam. At that meeting I met an engineer named Wolter who showed me a really interesting project that he was working on and needed some assistance with. The UI for the project consisted of a 4x4 matrix keyboard connected to the BASIC Stamp through a 74C922. His demo used the DEBUG window, but ultimately he would install an LCD for local display.

After returning to Texas, I had a couple of idea exchanges with Wolter. His use of the 74C922, and wanting to use an LCD, tickled my interest. I remembered seeing this combination, and finally found it, by digging through my old documentation.

Way back in the early days of the BASIC Stamp, my buddy, Scott Edwards (the creator of this column), had designed such a project with the BS1, and very cleverly came up with a scheme that allowed the 74C922 and the LCD to share the same I/O pins. This makes perfect sense from a resource conservation point-of-view, since the Stamp can't write to the LCD and read from the 74C922 at the same time. So we're going to use Scott's hardware design with a BS2 and imitate a controller that I recently encountered.

Okay, what am I imitating? Well, not long ago I needed some extra storage space so, like many people, I went and rented a small room from one of those 24-hour-access storage companies. After signing the paperwork, I was asked to give them a four-digit access code of my choosing. The manager programmed the code into a computer, then took me outside to the gate-access point to show me what to do with the code.

Just before the entry gate was a small box with a telephone-style keypad and an LCD display. The instructions were quite clear: Press the [*] key, enter your access code, then press the [#] key. If the code was correct and my bill was paid up, I would be welcomed to come in and have access to my storage unit. The manager told me that if I ever had a problem with my bill, I'd get a small message to see her. I assured her there would be no problem — and, of course, there hasn't been.

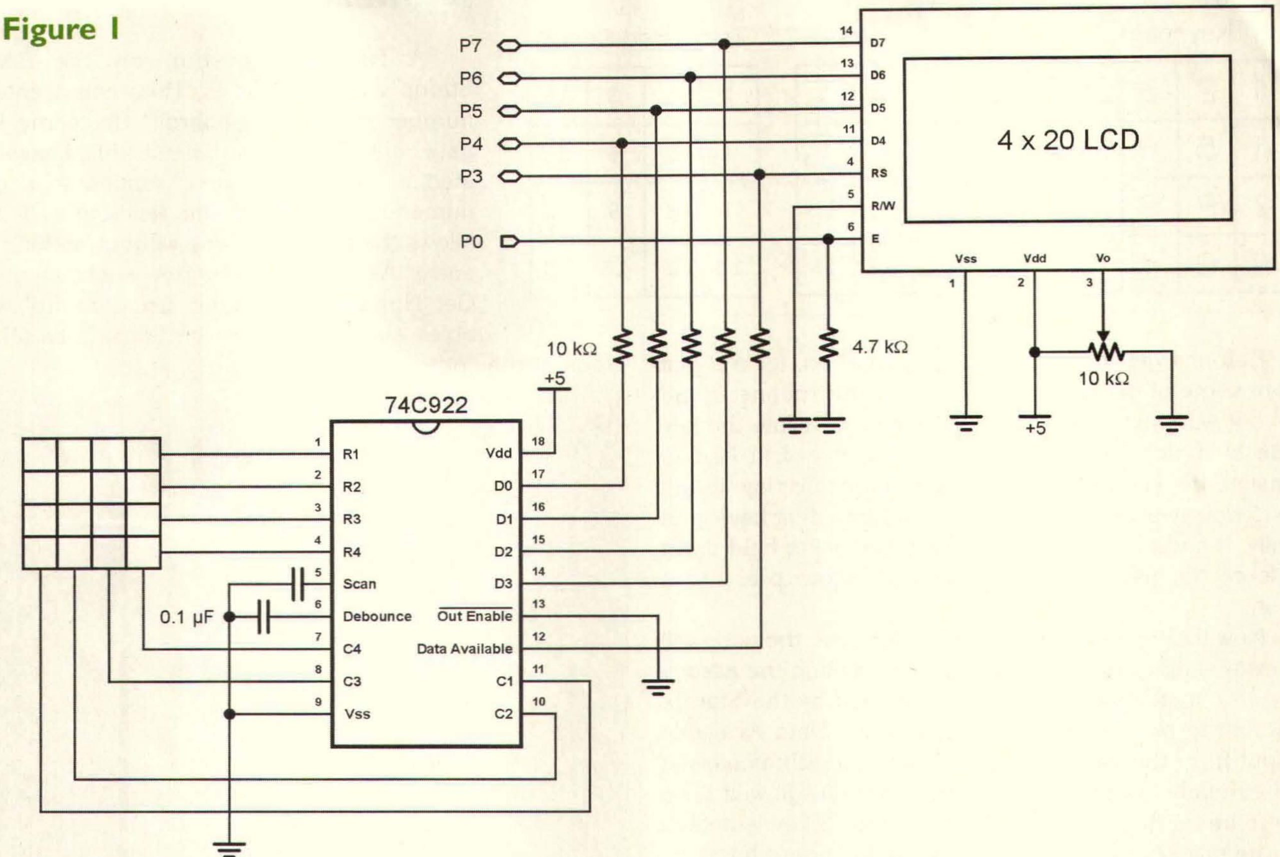
After unloading some boxes into my nice, new storage room, I found the same type of control box on the exit of the facility. Getting out was the same as getting in, and I had no problem. As I drove away I thought, "You know, I could have done that with a BASIC Stamp." So now I will.

Share and Share Alike

As I already mentioned, the hardware we'll use here was designed by Scott Edwards, and is typical of his clever use of inexpensive components. Take a look at Figure 1. The outputs of the 74C922 are connected to the same pins used by the LCD buss and RS line through 10K resistors. The way the 74C922 works is very simple: When a key has been pressed, the Data Available pin goes high and the key value (0-15) is output from D0-D3. When the Stamp pins are configured as inputs, the 10K resistors simply act like pull-ups and pull-downs so the pins can be read without any difficulty.

But won't we have a problem when we want to write to the LCD? Nope. Let's say that we want to send a high out to the LCD. If the associated 74C922 pin is also high, then there is no issue (no current

Figure 1



flow between Stamp and 74C922). If the 74C922 pin happens to be low, the high from the Stamp is felt across the 10K to the LCD. Again, no problem. Of course, the process is identical — just flipped — if we want to send a low to the LCD. That Scott Edwards is a very clever guy, isn't he?

From a software standpoint, there is no real challenge. We simply need to remember to make the buss pins inputs so we can read the 74C922 and make them outputs when we want to send data to the LCD. We can do that with just one line of code in each section.

Keyboard Input

After deciding to imitate the gate-entry controller, I popped over to Tanner Electronics in Dallas and picked up a 74C922 and a Velleman 4x4 matrix keyboard. I put together a piece of test code and ran into my first problem to solve when using the keyboard and 74C922.

If you look at Figure 2, you'll see how the keyboard is laid out, how the raw values are returned, and how I actually needed them to be (in order to match the keyboard). Thanks to the utility of the PBASIC programming language, the translation is easily handled with one line of code. Though, as you'll see, I spread that single line across many to make it easier to read.

Let's go ahead and look at the code for reading a key. I made the decision that this subroutine would actually wait for a key before returning. Obviously, waiting doesn't work for all applications. In those cases where waiting is not possible, we'll simply check the Data Available (aliased as KeyReady) line externally before calling this code.

```
Get_Key:
  DirL = DirL & KeyCfg
  DO : LOOP UNTIL (KeyReady = Yes)
  keyIn = KeyPad

  LOOKUP keyIn, [  1,  2,  3, 10,
                   4,  5,  6, 11,
                   7,  8,  9, 12,
                  14,  0, 15, 13  ], keyIn

  LOOKUP keyIn, ["0123456789ABCD*#"], char
  IF (showNum AND (keyIn < 10)) THEN
    GOSUB Print_Char
  ENDIF
  IF (showExt AND (keyIn > 9)) THEN
    GOSUB Print_Char
  ENDIF
  IF (release = Yes) THEN
    DO
      PAUSE 5
    LOOP WHILE (KeyReady = Yes)
  ELSE
    PAUSE KeyDelay
  ENDIF
  RETURN
```

Figure 2

Keyboard

1	2	3	A
4	5	6	B
7	8	9	C
*	0	#	D

Raw Codes

0	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15

Translated Codes

1	2	3	10
4	5	6	11
7	8	9	12
14	0	15	13

Before I get into a detailed explanation, let me just share some of my design decisions for this routine: it had to work with shared LCD lines; it had to translate the key code to match the printing on the keyboard; it had to translate the key to an ASCII character for display; it had to selectively allow display of digit and non-digit keys; and finally, it had to create a delay for a key being held down or force the user to release the key before pressing it again.

Now that you know the design decisions, the code will be even simpler to follow. We start by making the associated I/O lines inputs so they can be read by the Stamp. The first to be checked, of course, is the Data Available output from the 74C922, which the program has aliased as KeyReady. As you can see, the program will wait for a key to be ready using a **DO-LOOP**. Once a key is detected, the raw key value is read from the keyboard buss.

Translating the raw key code to a value that matches the keyboard layout is a simple matter of using **LOOKUP**. One of the new features of the PBASIC compiler is the ability to break long lists over multiple lines (at the commas). We can take advantage of that feature with our translation code, and even format the line so that the translation table matches the keyboard exactly. Once we have the translated key code, deriving the ASCII character for it is accomplished by using another **LOOKUP** table.

This subroutine uses control variables to determine the rest of its behavior. The first is a bit called showNum that, when set to one (Yes), will allow the routine to print the ASCII value of the key characters "0" to "9." The next control variable is called showExt (show extended). Its purpose is to allow the display of the characters beyond the numeric set. In the case of the keyboard I used in my project, it has four hex characters, a star, and the pound sign (it's a telephone keypad with "A"-"D" added).

Finally, the variable release controls key repeating. When release is set to one, the user must release the key before the next can be read. In this case, there is a short delay loop built in to prevent accidental repeating. When release is set to zero, a **PAUSE** is used to create a repeat delay for the key being held.

As you can see, this is a very robust input routine — I designed it that way. Many applications will have simpler requirements, and you can strip away those things not needed in these applications.

Numeric Input

A frequent question on the BASIC Stamp's mailing list is "How can I enter a number using a keyboard?" Since my little gate control application needs this, I have created a fairly full-featured routine to accept numeric input from the keyboard. It also allows the user to escape without making the entry. As with the Get_Key subroutine, the Get_Number subroutine uses control variables and even affects bit flags. Let's take a look at the code:

```
Get_Number:
  number = 0
  inDigits = 0
  hasNum = No
  showNum = No
  showExt = No
  DO
    GOSUB Get_Key
    IF (keyIn < 10) THEN
      IF (inDigits < maxDigits) THEN
        GOSUB Print_Char
        number = number * 10 + keyIn
        inDigits = inDigits + 1
        hasNum = Yes
      ENDIF
    ELSE
      IF (keyIn = StarKey) THEN
        hasNum = No
        EXIT
      ENDIF
    ENDIF
  LOOP UNTIL (keyIn = PoundKey)
  RETURN
```

The subroutine starts by clearing the return value (number), the number of digits entered (inDigits), and the flag indicating a valid entry (hasNum). It also clears the external display control variables, since the routine will want to examine the returned key before displaying it.

One of the control variables used is called maxDigits. This value will cause the routine to stop accepting value keys after a specified number of digits have been entered. Of course, the maximum number of digits that can be entered is five, but we must be careful because entering numbers like 99999 will cause a rollover error since it's greater than the 16-bit maximum value of 65,536.

What the routine does, then, is wait for a key, check to see if it's a digit (0-9), then checks to see if there are digits left in our entry field. If this is the case, the character is printed and the key added to the return variable. A flag variable, hasNum, is set to indicate that we have, in fact, entered a number.

To add the new key to our numeric value, what we need to do is a decimal left shift of the current value, and then add the new digit to the one's column. The decimal left shift is accomplished by multiplying the current numeric value by 10. This process moves the previously-entered digits to the left.

Once we've entered enough digits to fill the entry field, the routine will simply ignore any key except the star key (which is used for escape) or the pound key (which is used to accept the value). If the star key is pressed, you'll notice that the hasNum flag is cleared and the key input **DO-LOOP** is terminated with **EXIT**. Another way to end the entry loop is to press the pound key.

Advanced Use of Conditional Compilation

Back in March, I introduced you to another new Stamp compiler feature — conditional compilation. Most of the time I use this to set constants based on the connected Stamp, but we can also use it to determine code sections to compile based on our own settings.

Let's say, for example, that we didn't have a 4x20 LCD handy, but wanted to get started on the code while we waited for the good folks at Digi-Key to ship out our order. The Stamp compiler has a display feature built in (the **DEBUG** window) ... can we use it to prove our program while waiting on the display? Yes. Let me show you how.

Remember that conditional compilation control symbols are defined as either true (not zero) or false (zero). If the compiler encounters a symbol that has not been defined, it is assigned a value of false. I prefer to be very explicit in my declarations using zero and one. Like this:

```
#DEFINE __LCD = 1
```

I've made the decision to precede conditional compilation symbols with two underscore characters. This isn't a requirement, just the convention I've selected for myself. While I'm waiting for my LCD to arrive, I'll change the definition to this:

```
#DEFINE __LCD = 0
```

Note that we cannot use the constants Yes (1) and No (0) in our conditional compilation symbol definitions because conditional compilation directives are evaluated before anything else in the program, including constants definitions.

If you look back in the Get_Key subroutine, you'll see a call to a subroutine called Print_Char. Here it is:

```
Print_Char:
  #IF __LCD #THEN
    GOTO LCD_Write
  #ELSE
    DEBUG char
    RETURN
  #ENDIF
```

When the LCD is selected, the character (passed in char) is passed to the LCD_Write subroutine. Also note that **GOTO** is used here since there's a **RETURN** at the end of LCD_Write. What Print_Char becomes, in this case, is an entry to the subroutine LCD_Write. If the LCD is not selected, then the **DEBUG** window is used. What this means is you can run the program with or without the LCD. Likewise, one could develop a program that uses either a standard LCD or serial LCD.

One last note on conditional compilation — the directives actually control which lines of code are compiled and downloaded to the BASIC Stamp. Keep this is mind, since code compiled under one condition may need considerably more EEPROM space than under another. Remember that you can keep track of compiled code space with the Memory Map function in the editor.

With the grunt work out of the way, the rest of the gate-control code is fairly simple:

1. Display menu.
2. Wait for code.
3. Check code against known codes.
4. Open gate if code is valid.

The program takes advantage of techniques we've used in the past, including last month's suggestion to store strings in EEPROM. This is, of course, a demonstration program, but could certainly be developed into a full-fledged application using past projects, including the serial interface for updating the customer database, and a real-time clock to log entry and exit times.

Have fun with it, and Happy Stamping! **NV**

Resources

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The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Software Documentation

Software documentation has always been a special challenge, and will probably always continue to be so. However, there are ways to improve matters. We'll look at some basic problems, fallacies, and approaches to better software documentation. This information is based upon actual experience obtained from many large and small companies.

What is Documentation?

In the simplest terms, documentation is the *precise* description of the software. The term *precise* is a critical concept in documentation. A close hardware analogy would be the drawing package for a rack of equipment. This package contains the schematics of each piece of equipment, the mechanical layout and assembly of the components, an interconnect list, connector descriptions, operating instructions, and theory of operation.

Let's look at hardware documentation. No hardware engineer would think of producing a device without this drawing package. Yet, very often, software is developed, sold, delivered, and changed without any drawing package. The simple reason for this is that software is usually a personal activity, while a hardware product requires the interaction of many people. Managers can't see software in the same way as hardware. So they often don't know how to evaluate it. The bottom line is that if the software works, it must be okay. So, the programmer sits in his cubical with his computer, without any specific requirements other than to make it work.

Oftentimes, software documentation is nothing more than a few lines written by the programmer about what he did. It's usually written after the fact and in general terms (so that his supervisor will see what a good job he did). How long would a hardware designer last if he went in a corner for several months with a proto-board and wired up a complex circuit, then gave this circuit to his supervisor with a few sentences of what the circuit is supposed to do (not what it actually does), and perhaps a block diagram that he did from memory? It is obvious that the "hardware documentation" from this engineer is meaningless. It cannot be applied to the circuit if there is a question. It is not complete or precise. (Precision reflects the correspondence between what the documentation says and the circuit.)

Note: Precision is more important than completeness. This is because knowing exactly how one part works will help in understanding how the connecting parts work. On the other hand, information that appears complete, but is inaccurate, can be devastating in trying to understand something. That is why a schematic is so important — it is a precise description of the equipment. Much information can be inferred from a schematic.

The Fallacies of Software Documentation

1). There's no time (or money) to do it.

This is probably the most used argument. Documentation, without question, is a boring task. It's usually put off to the end of the project cycle when the time and money crunch is the greatest. The result is that the product is completed before the documentation is really started. It then seems difficult to justify the need for spending the time to document a working system. It seems that this "added" time comes right out of the profit line. Besides, the next project is coming up and it's much more interesting than documentation.

Answer: First of all, documentation should be an on-going task. While it is true that the *organization* of the documentation is necessarily done when the software is completed, the documentation data itself should be generated during the development of the software. In this way, the documentation will be complete and precise. Additionally, the time needed to compile the documentation into a single source will be minimal. The time for documentation should be allotted during the estimate for the software. It is just as much a part of the system as drawings are for hardware.

2). It's just for in-house use.

This argument suggests that, because only employees will use the software, that documentation is not necessary. It's not like we're selling a product or anything. After all, why does anyone else need to understand how it works, anyway? All they need to do is follow the directions.

Answer: There are several insidious assumptions in these statements. The first is that quality is not needed in-house. This is clearly wrong. Poor workmanship in tools will show in products that *are* sold. The second assumption is "if they can't understand it, then they need me." This is another name for job security. Bluntly, people who feel this way are typically marginal performers. This gives all the more reason for better documentation. The third assumption is that the software will never change. This is nonsense. Software always changes. In fact, the utility of software is that it's (supposed to be) easier to change than hardware. That's why software was developed and why computers are so powerful.

3). I know the software so no documentation is needed. (Or "Trust me. I know what I'm doing.")

This argument (similar to #2 above) suggests that the writer will live forever and never retire. "I've been here 10 years and know the software by heart. I don't need to waste time (see #1 above) on that. I'm a professional!"

Answer: This, too, has several subtle assumptions. The first is that only the programmer knows what documentation is needed. This is wrong because the programmer is clearly more concerned with job security and the existing state of affairs. There is also the snobbish attitude that the programmer cannot be criticized by anyone outside of the programmer's circle. This is why independent documentation standards were developed. The programmer is not always a good judge of what is needed.

4). If we need documentation, we'll hire someone. (Or "Give it to Mikey. He's a programmer. He'll fix it.")

This assumes that any experienced programmer can be called in at any time to correct any shortcomings in the software. After all, it should be an easy thing to do, shouldn't it? Most of the hard work is done ... the program works. All we need is a little cleaning up to make it look nice.

Answer: The truth of the matter is that only the easiest work has been done. Software development is a very personal experience. An experienced programmer cannot read the mind of the original programmer. In order to understand the software, the experienced programmer must: **1)** learn what the program is supposed to do; **2)** know the formats of the data coming in and going out; **3)** identify the appropriate variables in the program; **4)** understand the nuances of the code in order to learn the reasons for particular software approaches; **5)** organize the flow of the program; **6)** learn how to operate the program, and **7)** learn the original programmer's intentions. This is not simple. And, quite often, it is faster and better to scrap the existing software and start from scratch. No one, no matter how experienced in software they are, can be expected to unravel the intricate musings of another without great difficulty.

5). We've always done it this way.

This statement is usually found in a small shop where only one or two people work on the software. They are very familiar with it and see no need to put in the effort. This is really a composite statement of #3 and #1. Basically, this is a statement of ignorance. These people do not understand the benefits of documentation. They've never used it, so why start now?

Answer: Software is a living thing. It grows and changes with time. Small programs develop with time into more and more complex programs as hardware improves and requirements change. These simple programs become complicated programs. Changing them becomes more difficult. But, because the developer is ignorant of the benefits of documentation, the extra time and effort needed to change old programs and develop new programs is accepted without comment. These people simply don't know that there are better ways to do these things. And that these ways have been proven time and time again.

The Results of Poor Documentation

Poor documentation of existing software will cause problems in many areas. The obvious area is when a program change is needed. But there will be problems in the development of new programs, as well.

Consider a new programmer being tasked to write a new program. The first concern for the programmer is to define the specifications for the software. *This is important documentation!* It tells everyone what the program is supposed to do. Without these specifications, the software can be anything from laughable to dangerous. However, in a poorly documented shop, this information will be vague or non-existent.

Poor documentation in specifications results in poor software. Verbal specifications are generally worthless. Again, consider the hardware analogy. Would any engineer accept "specifications" for a device that were vague and verbal? "I need a device to measure wind velocity from a ship," may be a reasonable statement for an R&D effort. But no engineer would sign a contract for that without some very specific attributes defined. Software is no different. Precise specifications are the necessary documentation needed to start any software. These must be in writing, with enough precision so that there will be no argument at the end of the project as to whether the software functions as promised. It can be seen that poor existing documentation and poor specification documentation can severely affect software development.

Paying for Poor Documentation

Poor documentation slows the learning of software systems. What do the reports mean? How do I get a particular report? How do I run the program? How can I write a similar program to enhance existing software? Clearly, the lack of documentation is seen in all aspects of the software, not only in changing it.

The most obvious problems come when non-documented software has to be changed. Tremendous penalties are seen in time and money. Spending two weeks during development for proper documentation can save months of time during change. *The lack of proper documentation will always be paid for.* Saving time and money by ignoring documentation always results in spending much more time and money later. There are no exceptions. It's just a matter of time.

Lack of documentation hides errors and makes traceability difficult. Who knows what lurks inside the software if it can't be understood? What version of the software is appropriate for part ZXY? How can I be sure that this program is working right? Why is this procedure used instead of some other procedure? This is part of documentation's role.

Unprofessional Appearance

The final aspect of poorly documented software is in its appearance. It's not professional. It doesn't look or act like a professional product. Contrary to popular engineering belief, appearance is very important. The user sees this software in the same way he sees a front panel. No one would sell a product with a front panel labeled in tape and ballpoint pen. No one would accept switches or meters that were unlabeled. No one would allow sloppy workmanship that made the cabinet a mess. Yet, often software is sold with these equivalent defects.

This is because poor documentation makes the operation of any software difficult and awkward. The operator is expected to make up for the limits of the programmer. Reports are cryptic and need decoding. Labels are missing or poorly defined. Functions don't do exactly what is expected. The operator must remember special codes or responses. Inputs are not precisely defined. In short, poorly documented software is messy. It looks as if it was done in a slipshod manner ... regardless of how well it was written. This is because documentation extends to the operator interface. Poor documentation in one area is almost always followed by poor documentation in other areas.

What Software Documentation Should Consist of

1). Program specifications.

The first critical documentation item is the specifications of what the software is supposed to do. This must include the data going into the program and the data coming out. It must include all the functions that the program must perform. It must also include any theoretical, mathematical, timing, and reasoning considerations, as required. All of this must be precise. There must be input and output file record layouts of all data. There must be precise functional specifications. There must be no doubt in what the software must do. There must be no doubt as to how or why the software must operate. And there must be precise constraints placed on the software (speed, memory, etc.).

Sometimes, the programmer will not be given these because he may be the expert in this area. In that case, the programmer must prepare these specifications. And they must be reviewed and accepted by everyone that is appropriate. (If you asked a repairman to remodel your kitchen, wouldn't you require him to tell you exactly what he was going to do? What would you do if he said, "Trust me. I know what I'm doing."?)

2). Self-documenting code.

Probably the most important single aspect of documentation is the programmer's notes inside the body of the program. These notes tell the reader why and how things are done. Yet, this area of documentation seems to be overlooked. (Perhaps because the supervisor doesn't usually look at the code.) Properly documented code can be read by anyone to gain a detailed understanding of the software. It is the easiest and most direct method of documenting software. It is the fastest method of documentation.

These notes must be explicit in explaining what and why things are happening in the program. A note that simply restates the operation being performed is meaningless (i.e., "This statement adds X to Y" is meaningless. "This is an integration operation adding the last voltage sum with the new voltage measurement" is very meaningful).

Every paragraph must have a precise description of its operation. Any special operations within that paragraph must be pointed out and explained. Every line that contains a non-obvious instruction must be identified and its operation detailed.

All of this doesn't really take up that much time. It adds about 20 percent of the time to input the initial code. But it also makes the programmer think about what he is doing. So this time is not really wasted. The result is fewer bugs in the code and a better understanding of the code by the programmer. The time penalty for adding the notes is usually offset by faster debugging.

3). Structured code.

A lot has been said professionally about structured code. It means different things to different people. The definition used here is pragmatic. It is: Anything that makes the source code easier to follow and understand adds structure. Thus, convoluted logic lacks structure. Variable labels that are not intuitively obvious reduce structure. "Clever" programming tricks that are obscure reduce structure. Poor layout of the program itself subtracts from the structure of the program. A well-structured program has a very logical flow of paragraphs and functions. Those functions that happen at the start of the program appear first. Those functions that are often used by many different parts of the program are grouped and labeled as such. Variable names describe the data they hold. For example, PAGCNT holds the "number of pages." This has much more structure than P113. Each paragraph (subroutine) should have a single entry-point and exit. If the logical flow within a paragraph must be changed because of a variable, then that variable should contain a meaningful value, i.e., if the operation depends on the temperature, the variable should be TEMP=212, referring to degrees, or TEMP$="TOOHOT." The variable TEMPSWT=1 is a very poor choice ... it lacks structure. There are too many rules to specify here. And, sometimes the rules change, depending on the circumstances.

There is only one single rule that must be followed in order to write structured code. That rule is: Make all choices so that it is easy for someone else to understand the program.

4). Write down all change requests and program fixes.

This is such a trivial task. But it is very important, especially at the early stages of software implementation. These notes allow traceability of the evolution of the software. They help in finding bugs. Without these, the software becomes isolated in time. The original reasons for doing things becomes lost. Changes upon changes build complexity without the explanation of the underlying causes.

These change requests do not have to be formal ECRs (Engineering Change Request), although they could be. A simple memo or list of changes needed with a sentence or two explaining why the changes are needed is sufficient. If the above four items are done properly, then most of the remaining items of documentation can be created without too much effort. They will usually require only an elaboration upon what already exists.

5). Cross-reference listing.

These are computer-generated listings that identify where each variable is used. These are useful when changing a program so that one can determine if a change in one place will affect something in another place. It is important that these listings be accurate and up-to-date.

6). Paragraph descriptions.

Each paragraph (a logical section ... like a subroutine) in the program should be described in the documentation. This description should be precise in explaining what is happening. It should be detailed enough so that any bug that might occur in the future can be isolated to a particular paragraph or two. This should be written in simple English ... not jargon. And there should be explicit references to program variables or specific lines of code so that the reader can go directly from these descriptions to the program code.

7). Operating instructions.

Every operator response should be described and defined. This should explain what happens when key "X" is pressed. It should say when to press key "X." It should give the limits of the data to enter and an example. It should provide information about the software that would be useful to the operator. For example, how long it takes to run the program, what hardware is needed, how to hook up the hardware, how much memory the program needs, and any other information that could affect the program's operation that is external to the basic computer itself.

This *should not* be a walk-through of the program (i.e., "The CRT will display 'XZXX.' When this is seen, press *return*."). In terms of documentation, this walk-through is meaningless. It doesn't explain the program, it only describes it. Certainly, CRT displays and responses should be described and examples shown. But they should be used as aids to understanding how the program operates. Walk-throughs are not documentation. And they are poor training aids, too.

8). Theory of operation.

This discusses how the software solves the particular problem it was designed for. It explains the problem and tells why it is a problem. It discusses this particular solution and why it was chosen over other solutions. It shows the correspondence between (parts of) the solution and particular paragraphs within the program. It provides a general flow of how the program operates, again referring to paragraphs within the program. (This is the documentation that many people refer to when they say "documentation." But this is really only an overview. It is useful for building a general idea of what the software is doing. However, note that if the paragraph references are not included [#6 above], which is typical, then this documentation has little value.)

9). State diagram.

Many people will disagree with the

idea that a flowchart is poor documentation. This is because flowcharts have always been associated with programs and computers. However, while flowcharts have their uses in the classroom, their utility fades in real life. This is because a proper flowchart should show *every* decision and operation within the program. If the program is several thousand lines long, then the flowchart becomes impossibly huge. What's more, it must be done by hand (computer generated flowcharts are terrible) and is, therefore, inaccurate.

In addition, in a practical world, these flowcharts are rarely updated, so they become outdated, too. Typically, flowcharts are generated after the program is completed and show, in a general nature, what the program is supposed to do. In terms of documentation, this is neither complete nor precise. Therefore, it is not too useful.

A much better illustration of the software is in the form of a state diagram. This breaks the program down into functional segments and shows the logic paths between these segments. Each segment consists of one, or more, paragraphs that perform a reasonably isolated function. Whenever a different function is referenced, a line is drawn to that function. This shows the interactions of the functional parts of the software. This drawing is fairly direct and simple. Even large programs can be shown on a page or two. This provides a much easier (therefore, more complete and accurate) method of graphically representing the program.

Additionally, large and complex state diagrams can be sub-defined into more detailed state diagrams. That is, a single box in a state diagram can have its own state diagram. This hierarchy of state diagrams can be very useful.

10). Training course.

Probably the most overlooked aspect of documentation is in showing someone else how to use the software. This has two useful benefits. The first is obvious — the user learns how to use the software quickly and directly. This spreading of information is useful later if the program needs to be changed, because it may be the user that defines the changes needed or even makes the changes himself.

The second benefit is that the programmer finally sees exactly how the software is to be used. Quite often it is found that a simple change could make the software much more useful. But, without this opportunity of bringing the user and programmer together, the software often suffers. A training course (possibly just sitting down for an hour with the user, going over the software) should always be part of the documentation.

Conclusion

Naturally, the actual documentation for an embedded front-panel controller is very different from a payroll program. But, the concepts and objectives are the same. Documentation is a means of teaching someone else about what you've done. I've made comparisons to hardware to show how much more difficult software documentation is. This is because you can't hold a program in your hands and look at it like a piece of hardware. Software is an idea and has no physical existence that anyone can see.

Rather, it's a construction of concepts built with the creative mind of the programmer. Of course, it's hard to document. But, for these same reasons, it becomes that much more important to document it properly. **NV**

Tech Forum

QUESTIONS

I am looking for a kit or circuit for building a date/time generator for a CCTV camera/VCR set-up. I use a composite signal only.

I use my CCTV cam for recording lunar and planetary AVIs. I'm also seeking information or circuit on video integation.

#5031 **Bill Hepner**
via Internet

I own a DCT 1134 converter for cable. I have been in electronics all my life and would like to know more about this piece of electronics.

Where can I get a schematic for this unit? What is the phone jack in the back for? Is it for RS232 communications and, if so, what is the criteria for communication? There is a slot in the back, is this for programming the converter? What is the pinout on these jacks or connectors?

I do electronic repair and this has been the hardest piece of equipment to get information on.

#5032 **Normand**
via Internet

I would like to feed a security camera output to a VHS VCR to prevent unauthorized persons from entering a restricted area and using equipment (by which they could be injured).

My VCR can be easily controlled by CC relays, K1 to close for 115 VAC power, K2 to simulate the RECORD PB, and K3 to simulate the PAUSE function. K2 should energize after the tape is threaded during the power on. K2 should remain energized until the VCR power (K1) is removed (lights in room go off). The actual recording should then be controlled by K3 by using the PAUSE (PB) function for 15-30 seconds every two-three minutes (K2). I wish to use 555s not 4017s.

#5033 **Len Duncan**
Oceanside, CA

I am a hobbyist/experimenter and do most of my work on a traditional solderless breadboard. Unfortunately, my soldering skills aren't that good, but I'd really like to experiment with some of the new devices that are only available in a surface mount package. Any advice on how I can do this? Is there some sort of adapter or socket I can use?

#5034 **Jeffrey Schwartz**
via Internet

I have an old Dish TV satellite receiver that is a single LNB (we switched to cable). Is there anything it can be used for? Maybe picking up weather or some kind of free data? (I don't mean illegal hacking.) Or maybe connect a BASIC Stamp to it?

#5035 **Robert North**
via Internet

How can I use LEDs as a turn signal in a home-built car, I plan to build? I think 10 each would be enough for each signal device and I would recess them a 1/4". Another application for LEDs could be remote lighting of inspection panels around appliances or plumbing fixtures. But how to string them in a house is problematic.

#5036 **Jim Estes**

I'm finding voltage doubling circuits that need AC input. What about DC-DC?

#5037 **Aaron McKinnon**
Eastsound, WA

I fly frequently for work, and often I listen to the Air Traffic Control channel that is piped into the audio jacks on the seats in the plane. On some planes, there is a very annoying

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ANSWER INFO

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

level of 400 Hz interference, sometimes to such a degree that listening becomes almost impossible.

Can someone suggest either:

1. A readily-available (and inexpensive) inline filtering mechanism which can be plugged directly into the stereo headphone line? This should remove the 400 Hz noise and leave the remaining audio spectrum alone.

2. A simple circuit which could be built to do the same?

#5038 **Bob Nirenberg**
via Internet

I have a Gateway FPD1500 15" LCD Desktop Monitor with a failed backlight inverter (this is an almost current model, but Gateway will not service it or provide parts/assistance). The inverter is made by LG (or maybe LGPhilips, they won't help either) and is "LG1501 Rev. 4.0."

The one-amp fuse was blown, and I replaced it with a #30 wire-wrap wire, then the main FETs started smoking. With difficulty, I found the FETs to be IR FR5505s, and replaced both of them. It actually worked for 10 seconds, then they blew and started smoking.

Does anyone know of a source for parts, complete inverters, schematics, information, anything? Even connector pinouts to allow possible use of a completely different inverter?

#5039 **Barry Watzman**
Watzman@neo.rr.com

I am in need of a BASIC computer language that I can get into and run on my very old RadioShack TRS-80 Model #4 computer (please, no laughter) that will allow a variable expression to be used in 'GOTO N' and 'GOSUB N' statements; 'N' being a variable. For example:

```
10 A1=50
20 GOTO A1
30 PRINT"TEST FAILED"
40 END
50 PRINT"TEST PASSED"
60 END
```

I have been told that Micropolis BASIC would run on my TRS-80, but I can't find any information on this old BASIC interpreter. Can anyone help me?

#50310 **Stuart B. Wahlberg**
Blythe, CA

ANSWERS

[1031 - JAN. 2003]

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

The IEEE 1394 is a high-speed serial bus that allegedly provides enhanced PC connectivity for consumer electronics audio/video (A/V) appliances, storage peripherals, other PCs, and portable devices.

This page **www.microsoft.com/hwdev/bus/1394/default.asp** includes links to a large array of information related to IEEE 1394, including a link to Global Engineering Documents **http://global.ihs.com/** Where you can purchase a copy of the associated standards or at least search for them. Once you have the right standard number you might be able to get a copy from your local library. A quick search turned up :

ETSI TS 102 813
Revision: 02 Chg: Date: 11/00/02
DIGITAL VIDEO BROADCASTING (DVB); IEEE 1394 HOME NETWORK SEGMENT

I'm not sure this is the document you are looking for. If it is, you can purchase a hardcopy or download a copy from Global Engineering Documents for $30.00.

Tom Tillander
via Internet

[2032 - FEB. 2003]

I have an aftermarket CD player in my car that came with an infrared (IR) remote that mounts on the right side of the steering wheel. However, I need to mount it on the left side.

I need a wired IR repeater in which I can mount the IR sensor on the left dash, run a wire to the center console, and have an IR LED retransmit the signal to the radio.

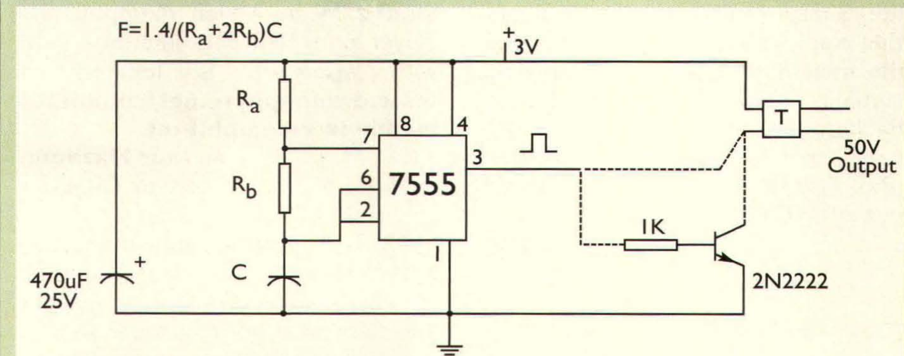
#1 Try using a fiber optic cable from the transmitter to the receiver. I

[3033 - MAR. 2003]

I'm looking for a 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.

A CMOS 7555 will do the trick for you. This chip can be configured to operate anywhere from less than 1 Hz to about 100,000 Hz by simply changing the value of either a resistor and/or a capacitor. Below is the basic circuit to use. The chip will output about 100 mA by itself, but a transistor can be added to switch power to your transformer, if you need more. I recall that you only needed a few mA at 50 volts. Happy Circuiting!

Craig Shippee
South Walpole, MA



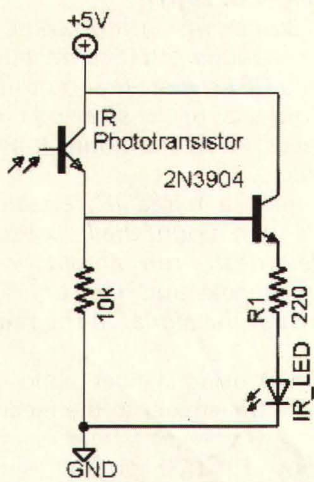
have been able to control a dish satellite receiver with more than 200 feet of cable used for PC serial port communications. RadioShack has fiber optic cable.

You can also try fixing small mirrors on the CD player and/or the transmitter to reflect the infrared signals.

I use a mirror in my hall to reflect my VCR remote signal to the VCR in the living room when I am in bed (a distance of 35 to 45 feet) and it works great.

Rick AI5H
via Internet

#2 You can try a simple IR detector/emitter pair.



You just need to mount the IR phototransistor on the left, near where the receiver will typically be, and the IR LED in front of the receiver on the CD player. All parts should be available at RadioShack.

For power, you could use some AA batteries or run a 7805 five-volt regulator from the 12 volts of the cigarette lighter jack.

You might also try using one of the Sharp modulated IR detectors that RadioShack sells. If by chance the transmitter operates on 40 KHz signals, it would help block out background noise. Also, you might need to use a more sensitive phototransistor and/or more powerful IR LED.

Evan Dudzik
Orono, ME

[2036 - FEB. 2003]
Where can I find a MM5369 60 Hz timebase chip? It seems to be obsolete and very hard to find.

#1 One place in particular seems to have almost all of the oddball chips I have looked for. This particular chip — the MM5369 — was used in an old regency K500 scanner I once had. The place to get these is through **www.onlinetechx.com**. Note the strange spelling of the word techx. I already did a search on the website and they are available.

Terry Kasie
via Internet

#2 The MM5369 Timebase chip is available from Comptronics, Inc. They have 40 in stock. Contact Doug at **1-800-800-9107**, or you can email same at **Doug@icparts.com**.

Joseph Kish
Clackamas, OR

[3031 - MAR. 2003]
I have a "Media Vision" CD player (Model: Memphis), with a nice set of detachable Bose speakers. I want to connect the speakers to another audio source/computer, and I need the pinout of the DIN connector attached to the speaker cable.

#1 Media Vision is permanently out of business, however, some technical, files, and support pages can be found at these websites. The Memphis unit is part #660-0019-01.

www.dragonphyre.net/complete/mediavis/smemph.htm

www.dragonphyre.net/complete/mediavis/tmemph.htm

A complete diagram and layout for the Media Vision Memphis CD Player and Memphis Interface card with speakers is located at **www.dragonphyre.net/complete/mediavis/bmemph.htm**.

Arthur Hazboun
Harbor City, CA

#2 This is basic "light bulbs and batteries" stuff. You can determine the continuity and polarity of a set of speakers with nothing more than a nine-volt volt battery and a snap-on connector. Open up the speaker boxes and start touching the wires from the battery connector to contacts in the speaker connector. When a speaker cone moves toward you, you have found which pins are connected to it and demonstrated what is called "positive" polarity. The battery wire which is connected to the positive voltage of the battery is connected to the speaker terminal which is to be labeled "+".

Chuck Larson
Largo, FL

[3032 - MAR. 2003]
I've always enjoyed singing my own lyrics to popular songs (parodies). It would be a great kick, however, if I could hear the original artist sing my lyrics.

My thoughts are along the lines of a DAW (Digital Audio Workstation). A scenario might be, playing several of the artist's tunes into the computer's memory to "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.

Digitally modifying a song so that different words are heard in the original singer's voice is a tall order. What you're asking for is speech synthesis, not audio editing. In many cases the exact speech sounds that you want will not be present in the original at all, so it's not just a matter of moving things around or making changes in pitch or loudness.

If you had a really large sample of the original singer's voice, not just one song, you might begin to make a start. But you would need more than one instance of every speech sound, because adjacent sounds influence each other; for example the K in "kitten" is not the same as the K in "ask" or even "koala."

And there is certainly, at present, no software that can listen to a song and make words come up on the screen for you to edit.

Michael A. Covington
Athens, GA

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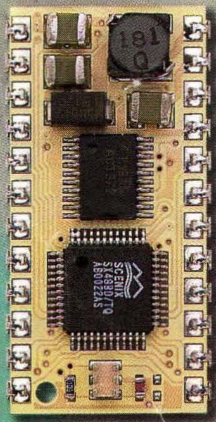
Javelin Applied

Parallax offers Javelin Stamp Applications with source code for free download at www.parallax.com

Here is a list of the available files. Check our website for new updates!



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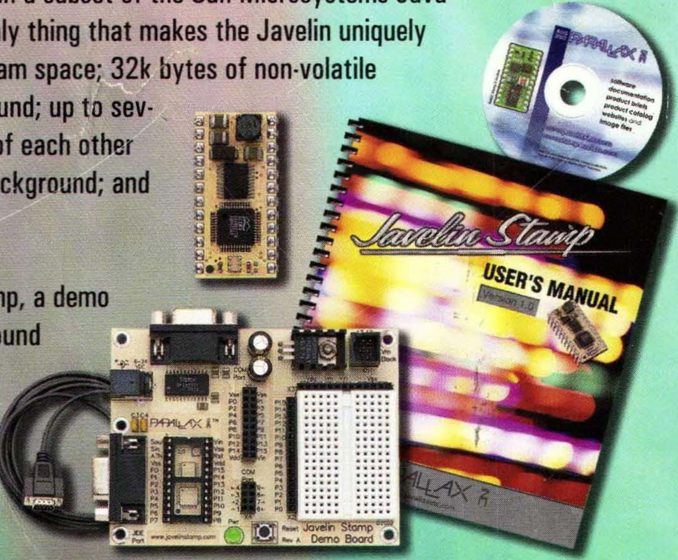
AN010	**Using a Serial Mouse with the Javelin**
AN011	**32-bit Integer Math for the Javelin**
AN012	**The text format library**

The Javelin Stamp is a 24-pin DIP module programmed in a subset of the Sun Microsystems Java™ language. The Java programming language is not the only thing that makes the Javelin uniquely different from BASIC Stamps: 32k bytes of RAM/program space; 32k bytes of non-volatile EEPROM; buffered serial communication in the background; up to seven UART objects that can communicate independently of each other and the main program; pulse width modulation in the background; and 8000 instructions/second execution speed.



The Javelin Stamp Starter Kit includes the Javelin Stamp, a demo board with dual serial ports to demonstrate the background UART capability, software, manual, serial cable and some electronic components.

Javelin Stamp Module; #JS1-IC; $89.00
Javelin Stamp Starter Kit; #27237; $239.00

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