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Nuts & Volts

August 2003
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Although much smaller than its namesake, this "Big Ben" clock has a unique LED twist.

Simple VHF TV Transmitter

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Software For Audio Testing

Electronics Q&A

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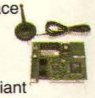

- 'Symphony' 32-bit PCI interface
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- Boxed, w/CD, manual, 90-day warranty

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- Belden 1696A digital audio cable
- 110 ohm, 22 ga. stranded pair
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Electric Field Meter


- Measures radiation from cell phones microwave ovens, computers, 'bugs', security, two-way radios...more...
- Range: 10MHz to 4.5GHz
- Meter and LED displays
- See pg. 60, Feb. QST mag.
- New,90-day warranty

HSC#ZAPCKR $89.95!

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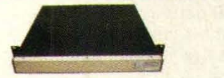

- Heavy grade, std 19" spacing
- 15 5/8"W x 16"D x 1 3/4"H
- Reversable mounting flanges
- Pulls from wrkg service, some scratches

HSC#19437 NOW...2/$19.95!

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- Model No. QM318200TD SCA Drive
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HSC#19335 $17.95!

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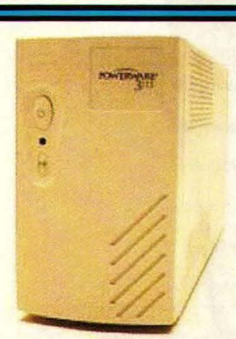

- **Input: 88 - 142 VAC**
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- **6.1"H x 3.4"W x 12.7"D**

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Hitachi Display


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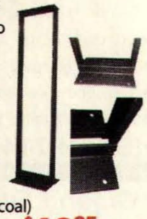
Circle #72 on the Reader Service Card.

19" Rack Mount



7 ft. tall 19" wide rack mount. Ideal for audio or networking equipment. Unassembled with 2 base angles, 2 top angles & hardware. Choice of charcoal or mill finish.

No. 220-0378N (charcoal)
No. 220-0380N (mill) $69.95 (ea.)

Mini 6/12 Volt Siren

Mini siren requiring 6/12 volts DC with 7" leads. Dimensions 2-3/8" x 1-1/2" x 1-1/2". Big sound!

No. 180-0113N
Price ~~$12.95~~ $4.95 (ea.)

Rack Keyboard & Mouse Tray

APC AR Rack Fits in 19" rack 23 lbs weight Gray color.

No. 220-0376N $49.95 (ea.)

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These tiny magnets are so powerful, they still hold strong through a human finger. Each one measures 3/8" diameter x 3/16" thick.

No. 380-0095N

50¢ (ea.) or 3 for $1.00

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A black mini light box with back lighting and a high intensity LED bottom light is great displaying your small valuables or any number of other items. Measures 9.75" deep 8.25" tall and 6" wide. The inside display area is 4" deep 6.25" tall and 5.5" wide. It has a translucent back and a hole on the bottom for uplighting. Power comes from a 115VAC to 12VAC wall transformer. Back lighting comes from a 5.25" mini fluorescent bulb (F4T5/CW) and bottom lighting from a circuit board with 15 high intensity LEDs.

No. 360-0548N $15.95 (ea.)

Same as above, but with 1,"U" fluorescent tube FT18DL/830)

No. 360-0549N $15.95 (ea.)

12 VDC Hobby Motor

High speed hobby motor boasts over 16,000 RPM at 12 VDC. 1.2 Amp Overall size: 1-1/2" diameter x 3" long. 1/8"(D) x 3/8"(L) Splined shaft. Two 2.5mm mounting holes on face are 1" O.C. This motor is also reversible. MFG: Johnson

No. 420-0570N
Price ~~$6.00~~ $1.25 (ea.)

12 VDC Worm Gear Motor

12 VDC worm gear drive motor has two speeds. High speed is 106 RPM at 4A, and low speed is 41 RPM at .91A. A 2.25" offset is attached to the 3/8" threaded shaft. The offset has a universal joint on one end. Originally designed as windshield wiper motor for 2000-2001 Saturn "L" Series cars.

No. 420-0578N
Price ~~$19.95~~ $12.95 (ea.)

115VAC 4-5/8" Ball Bearing Fan w/ tach

115 VAC 50/60 HZ, 18 Watts, 106 CFM, 5-Blade Metal Construction, Metal Body Construction, Ball Bearing, Terminal Leads, Size: 4-5/8" SQ x 1-1/2". Fan also has three wire signal generator output. MFG: Papst.

No. 290-0671N
Price ~~$19.95~~ $11.95 (ea.)

1000VA Uninterruptible Power Supply

Only 7" x 8.8" x 17.1" and weighs 43 lbs. Has 6 protected outlets and a network interface surge protection. MFG: NCR MFG P/N: 4071-1020-7194

No. 220-0314N $179.95 (ea.)

400 Watt Metal Halide Light with Bulb

Model MHSE-W-400-277F-F1. 18" diameter aluminum shroud with glass bottom. 277/120 V (currently wired for 277v but can be easily changed). Great for warehouse, grow lights, barns or other indoor use. This item must be shipped oversized. Please call for shipping charges. Used, excellent condition.

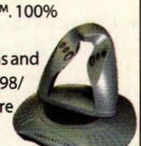
Part No. 360-0554N $69.00 (ea.)

Gentact 10" Linear Actuator

Operates on 24 VDC, includes attached 115 VAC converter. 18" long retracted, 28" long fully extended, 9.5" wide, 5" high. Includes wired remote control. Torque rating of 1300+ pounds! Limit switch at both ends. 110 to 24 VDC converter has a safety switch.

No. 340-0001N
Retail ~~$149.95~~ $89.95 (ea.)

Fragmaster Joystick Controller

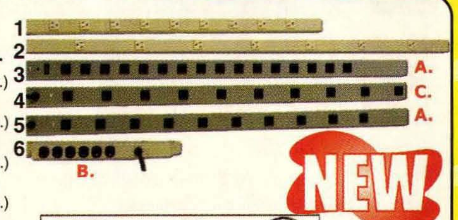


Designed specially for personal shooter games such as Quake™. 100% digital with 10 programmable buttons and triggers. Windows 95/98/ME compatible software included. MFG: Thrustmaster

No. 220-3542 $6.00 (ea.)

SL Waber Power Strips

	Part No.	Outlets	Length	Features	Price
1	280-0412N	9	36"	15A, 120V permanent mount	$19.00 (ea.)
2	280-0413N	8	60"	15A, 120V permanent mount	$19.00 (ea.)
3	280-0406N	16	48"	20A, 125V w/cord, blue/grey	$34.00 (ea.)
4	280-0409N	10	48"	15A, 125V w/cord, blue/grey	$24.00 (ea.)
5	280-0405N	10	48"	15A, 125V w/cord, blue/grey	$29.00 (ea.)
6	280-0423N	6	19"	20A, 125V w/cord, rackmount	$19.95 (ea.)



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Contents

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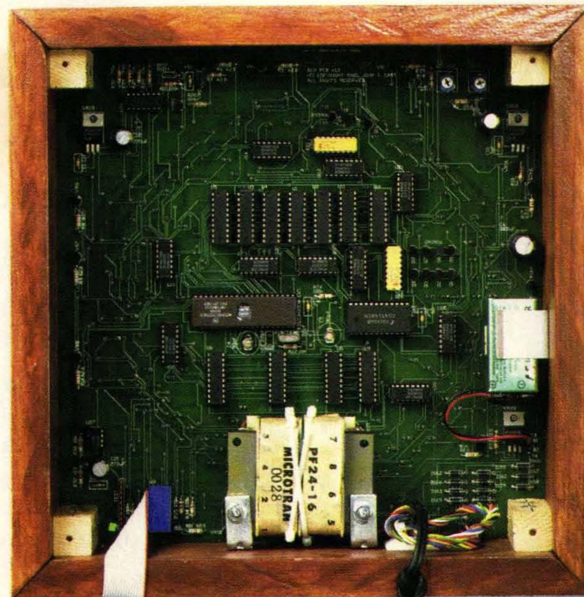
COLUMNS

Nuts & Volts (ISSN 1528-9885/CDN Pub Agree#40702530) is published monthly for $24.95 per year by T & L Publications, Inc., 430 Princeland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: Send address changes to **Nuts & Volts, 430 Princeland Court, Corona, CA 92879-1300** or Station A, P.O. Box 54, Windsor ON N9A 6J5.

Everything For Electronics
Nuts & Volts
Vol. 24 No. 8



Inside the Ben Clock. See article on Page 36.

NEW Robotics Magazine

The Amateur Robotics supplement to *Nuts & Volts* has become *Servo Magazine*. Check Page 20 for details or see **www.servomagazine.com**

DEPARTMENTS

Dear Nuts & Volts:

Congratulations on the new look at *Nuts & Volts*! The wonderful variety of articles is reminiscent of the excitement stimulated by *Popular Electronics* and *Radio-Electronics* back in the mid-1970s when a previous generation of hobbyists was making the move into digital electronics.

Best Regards,
Forrest M. Mims III

Dear Nuts & Volts:

Reader Kevin Kaas' complaint that circuit analysis using Conventional Current Flow is "outdated" because electrons happen to carry a negative charge makes about as much sense as an argument that flat maps are "outdated" because the earth happens to be roughly spherical.

The polarity (and quantization) of charge carriers does indeed come into play when explaining the physics of electron tubes, but this fact does not in any way invalidate the universal agreed upon definition of current flow as the net transfer of positive charge.

This mathematical convention is not scientifically controversial, bewilders no one, and is not in conflict with electron flow. Vacuum tube circuits are analyzed just as readily as solid-state circuits using CCF and Kirchoff's Laws. Maxwell's equations help explain rainbows, black holes, and radios, yet we don't utilize them to grind prisms or match antenna impedances. Stubborn resistance to important and useful simplifying models cannot aid in furthering one's understanding and practice of science.

Christopher Burian
Waltham, MA

Dear Nuts & Volts:

In Gordon McCombs Robotics Resources column April 2003, he had a side bar on material, specifically the section about thickness of materials. He went on to say that 1 mil was equal to 1 millimeter. While that is true in Europe where the Metric system prevails, in the US, a mil is one thousandth of an inch. Very different. Heights, widths, lengths, and depths are listed on products in US and Metric, but thicknesses are listed in mils (thousandth of an inch) and in decimal fractions of an inch. Never in Metric "mils." Take a look at inkjet photo paper, a regular sheet is 4 mils, card stock is 10 mils, and they don't

Continued on Page 58

Correction:
The correct URL for the May '03 Q & A "Cool Web Sites" SPICE simulations is ***http://email.e-insite.com/cgi-bin2/flo/y/eLJHOEijIq0DaS0Bu1COA1****.*

Correction:
There were two incorrect numbers published (102 and 10-4) in Thomas Henry's Learning Forth article (July '03). The numbers should have read "A pocket calculator might display this as 5.076666E2 which means we are to multiply 5.076666 by 10^2*. Taking this one step further, a computer representation could be made with the two simple integers 5076666 and -4. The interpretation, of course, is that we're to think of 5766666 as being multiplied by* 10^{-4}*.*

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

Subscription Order ONLY Line
1-800-783-4624

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✔ Line level inputs with RCA connectors
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✔ Microprocessor controlled
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✔ Tunes the entire 550-1600 KHz AM band
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Super broadband preamp from 100 KHz to 1000 MHz! Gain is greater than 20dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.
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- ✔ Watch the magnetic field of the earth!
- ✔ Sense different magnetic poles!
- ✔ Detect RF transmitter fields!

This really neat project actually senses and detects magnetic fields, RF fields, and electric fields! The TFM3 has three separate field sensors that are user selectable to provide a really cool readout on two Sci-Fi styled LED bargraphs! Utilizing the latest technology, including Hall Effect sensors, you can walk around your house and actually "SEE" these fields around you! Also detect radiation from monitors, TV's, electrical discharge, and RF emissions. You will have fun finding these fields and at the same time learn the technology behind them. Runs on 6VDC (4 AA batteries, not included). Live long and prosper!

TFM3	**Tri-Field Meter Kit**	**$39.95**
CTFM	**Matching Case & Knob Set for TFM3**	**$29.95**

High Power LED Strobe Light

- ✔ No more HV or Xenon strobe tubes!
- ✔ Super Bright LED's - won't burn out!
- ✔ Audio triggered or variable flash rate!

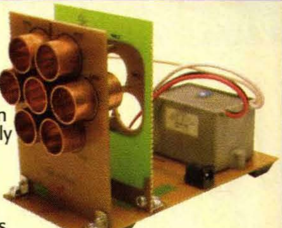
NEW!

LEDS9 (Included) LEDS8 LEDS20

A 3x3 array of super bright Telux™ LED's creates a brilliant sharp flash just like a Xenon flash tube. In the standard flash mode, a variable rate control varies the flash frequency from approx 1 to 220 flashes per second. In the audio sync mode, the flash is triggered by any audio input you provide into the standard RCA audio input connector. Built-in low and high pass filters allow you to select either bass or treble music triggering! An external trigger in/out connector lets you connect multiple units together for simultaneous flash. 3x3 array of LED's can be installed directly on the PC board, or on the external LEDS9 board (included) for case-top or remote locations. Optional display boards with 8 or 20 LED's are available for even more strobing power! Just imagine surrounding your room with a few of these, triggered to your stereo! Be one of the first to experience the new high output LED's of 2003!

LEDS1	**High Power LED Strobe Light Kit**	**$39.95**
CLEDS	**Matching Case & Knob Set For LEDS1**	**$14.95**
LEDS8	**Display Board, Inline with 8 LED's**	**$17.95**
LEDS20	**Display Board, 5x4 Array Of 20 LED's**	**$29.95**
AC125	**110VAC Power Supply**	**$9.95**

Ion Generator

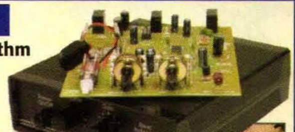


- ✔ Negative ions with a blast of fresh air!
- ✔ Generates 7.5kV DC negative at 400µA
- ✔ Steady state DC voltage, not pulsed!

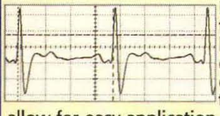
This nifty kit includes a pre-made high voltage ion generator potted for your protection, and probably the best one available for the price. It also includes a neat experiment called an "ion wind generator". This generator works great for pollution removal in small areas (Imagine after Grandpa gets done in the bathroom!), and moves the air through the filter simply by the force of ion repulsion! Learn how modern spacecraft use ions to accelerate through space. Includes ion power supply, 7 ion wind tubes, and mounting hardware for the ion wind generator. Runs on 12 VDC.

IG7	**Ion Generator Kit**	**$64.95**
AC125	**110VAC Power Supply**	**$9.95**

Electrocardiogram Heart Monitor



- ✔ Visible & audible display of your heart rhythm
- ✔ Re-usable sensors included!
- ✔ Monitor output for your scope
- ✔ Simple & safe 9V battery operation



Enjoy learning about the inner workings of the heart while at the same time covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The three probe wire pick-ups allow for easy application and experimentation without the cumbersome harness normally associated with ECG monitors. Operates on a standard 9VDC battery. The ECG1 has become one of our most popular kits with hundreds and hundreds of customers wanting to get "Heart Smart"!

ECG1	**Electrocardiogram Heart Monitor Kit**	**$39.95**
CECG	**Matching Case & Knob Set For ECG1**	**$14.95**
ECG1WT	**Factory Assembled & Tested ECG1**	**$89.95**
ECGP10	**Replacement Reusable Probe Patches, 10 Pack**	**$7.95**

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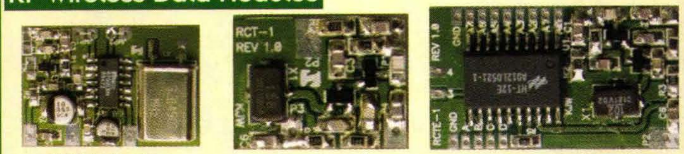
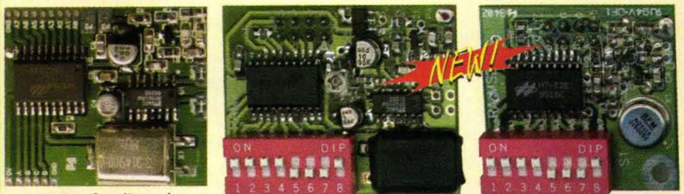
PL130	**130 In One Learning Lab Kit**	**$39.95**
PL300	**300 In One Advanced Learning Lab Kit**	**$64.95**
PL500	**500 In One Super Learning Lab Kit**	**$159.95**

RF Wireless Data Modules



RX Data Receiver TX Data Transmitter TXE Transmitter/Encoder



NEW!

RXD Receiver/Decoder RXDA Receiver/Decoder TXEA Transmitter/Encoder

- ✔ 433 MHz or 916 MHz data transmission
- ✔ Factory assembled and tested!
- ✔ Encoder/Decoder models for security issues!

Now you can build those special remote control projects in a flash, and have the ultimate in reliability...and security!

Unlike other units on the market, these units are crystal controlled for no frequency drift, yet are ultra small and very low power. These wireless RF link boards are perfect for any wireless application- sending data, car alarms, door openers, home security, electronic monitoring...you name it. All modules are pre-assembled and tested so you can start your project today! Two versions are available - 433 MHz and 916 MHz, 916 units can use shorter antennas (3 inches) and are better in high RF environments, while the 433 units have better range but need larger antennas (7 inches). NEW for 2003! A-Series modules include a programmable dip switch for encoder/decoder settings, and common dual row pin-outs for easy integration into your equipment!

RXD433A	**433 MHz Receiver/Decoder Module w/Dip Switch**	**$39.95**
TXE433A	**433 MHz Transmitter/Encoder Module w/Dip Switch**	**$37.95**
RXD433	**433 MHz Receiver/Decoder Module, Assembled**	**$34.95**
TXE433	**433 MHz Transmitter/Encoder Module, Assembled**	**$32.95**
RX433	**433 MHz Data Receiver Module, Assembled**	**$29.95**
TX433	**433 MHz Data Transmitter Module, Assembled**	**$24.95**
RXD916	**916 MHz Receiver/Decoder Module, Assembled**	**$34.95**
TXE916	**916 MHz Transmitter/Encoder Module, Assembled**	**$32.95**
RX916	**916 MHz Data Receiver Module, Assembled**	**$29.95**
TX916	**916 MHz Data Transmitter Module, Assembled**	**$24.95**

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4 Channel Usability
Receiver Equipped with Auto-Switching Capabilities

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- 2.4 GHz; Transmitts Up To 500 Meters In Open Area
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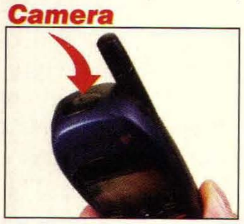
Camera



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Open Communication

Licensing and Certification: The *HOT* Tickets for New Communications Jobs!

During this economic downturn and the tech sector slump, those of you looking for a job in communications need all the help you can get.

With jobs so scarce in all areas of electronics, it is to your benefit to have all the credentials and experience possible to be in the competition for the few good jobs that are available. While your basic technical education and experience count most, it doesn't hurt to also have a certificate or diploma specifically saying that you are knowledgeable and competent in communications technology.

Such certificates are readily available to you in the form of FCC licenses or formal certification. If you are looking for a communications job, or any electronic job for that matter, and need a jump-start in applying for and landing a position, you should give serious consideration to these great professional credential options.

FCC License

The Federal Communications Commission (FCC) has been issuing commercial radiotelephone and radiotelegraph licenses for decades. These are *not* ham radio licenses. The commercial licenses are for those who perform work on some type of commercial radio equipment. The radiotelegraph licenses are for those who serve as a ship's radio officer, so they are not that useful. But just think about that as a career option. How about a job as radio officer on a cruise ship? Not bad duty if you can get it. Someone has to do these undesirable jobs. Most ship officer jobs go to those serving on tankers, freighters, and other cargo-carrying ships — good duty for a single person.

The radiotelephone license is more widely needed and recognized, and is an incredibly valuable credential. The FCC requires this license primarily for those who work on marine and aircraft communications equipment. You do not need it if you work on AM/FM/TV broadcast equipment, general communications devices like CBs, family radios, and commercial two-way radios.


Electronic certifications have been available for many years.

However, while the license is not needed in most communications jobs, many companies use this license to screen prospects for positions. Cell phone carriers, broadcast stations, telephone companies, and any organization with positions that involve installing, servicing, troubleshooting, and testing radio equipment can use the license as an entrance requirement. And most do. The license is a good indicator of what you know about basic electronics and radio communications fundamentals. As it turns out, most people holding the better communications jobs have this license.

The license is specifically known as the General Radiotelephone Operator License (GROL). It is obtained by passing a comprehensive examination in communications techniques, electronic fundamentals, and communications electronics circuits and systems. The exam is basically at the technician level, meaning that the math required is relatively simple — mainly algebra and basic trig. The exam is given by a number of organizations known as Communications Operators License Examination Managers, or COLEMs for short. These organizations are authorized by the FCC to conduct the exam. You can find them on the FCC's website. See the Resources sidebar. You can get an idea of what's on the exam be downloading a set of questions from the FCC website designed to help you study for the test. There are two parts to the GROL exam: Element 1 and Element 3. Element 1 covers the rules and regulations related to the jobs performed by a license holder. Element 3 covers basic electronics and some detailed questions about communications circuits, receivers, transmitters, antennas, and transmission lines, and digital fundamentals. It is a pretty comprehensive exam, but relatively easy to pass if you have any kind of electronic or communications education experience. But it not so easy that you can just walk in and expect to pass the first time without studying. Preparation is a must. More on that later.

The GROL also has a couple of interesting endorsements you can get by passing additional exams. One of the most popular is the Ship Radar Endorsement (Element 8), which covers radar principles, microwave components, and circuits and radar equipment. The second is the Global Marine Distress and Safety Systems (GMDSS) endorsement (Elements 7 and 9). The GMDSS license is required for ship radio operator positions. The Radar endorsement is a good one to get as so many communication systems are microwave.

If you work in the communications field, you really need the GROL whether your work requires it or not. It is a prestigious addition to your resume when you are applying for technician or engineering positions. And it may just give you the edge in getting that job. Give it some serious consideration.

Certification

Certification is a voluntary process of presenting your background to an independent organization set up to evaluate your qualifications in a specific field. Getting certified typically involves passing one or more exams related to the field. If you meet the qualifications specified by the organization, you become certified. Electronic certifications have been available for many years. Even so, you may not have ever heard of them. Electronic certifications have not been as visible or as popular as the more recent certifications covering the personal computer (PC) and networking fields. Most of these PC and networking certifications are so-called vendor certifications offered by companies that make networking hardware or software.

Some of the more popular PC and networking certifications are A+, Network+, and those offered by Cisco, Microsoft, and Novell. These certifications are very widely accepted by business and industry and are, in fact, the de facto hiring standards for networking personnel in most companies. While college degrees and experience are important, having a specific certification will get you the job faster than anything else. While electronic certifications are not as well known and recognized, they are still valuable in helping you get a job or advance on the job.

One of the most widely known electronic certifications is that offered by the International Society for the Certification of Electronic Technicians (ISCET). They offer a basic generic associate certification that validates your knowledge of electronic fundamentals. Then it offers more advanced and specific journeyman certifications in the various fields of electronics, such as communications, industrial, video, audio, biomedical, consumer electronics, computers, etc. Again, comprehensive exams are the basic route to the certification.

Another organization in the certification business is the Electronic Technicians Association International (ETA-I). They, too, offer a generic associate level electronic certification, as well as more advanced specialty certifications. They also have one devoted to communications. The Satellite Dealers Association (SDA) is also associated with the ETA. They offer a certification related to satellite TV installation and service.

Sources of FCC license education & preparation

Atlantic International Instutute
www.aiilearn.com
800-658-1180

Cleveland Institute of Electronics
www.cie-wc.edu
800-243-6446

Command Productions
www.LicenseTraning.com
800-932-4268

The Consumer Electronics Association (CEA) also has two certifications. The first one is the Mobile Electronics Certification Program (MECP) that tests individuals who want to install and service autosound security systems, and communications related products such as cell phones, satellite radios, and the like in cars or trucks. The second is a Wireless Certification Program for those interested in the cell phone field.

An engineering level certification for those in the telecommunications and broadcast fields is the one offered by the National Association of Radio and Telecommunications Engineers (NARTE).

Actually, they have both engineering and technician level certifications. NARTE also offers specialty certifications in electromagnetic interference/electromagnetic compatibility (EMI/EMC) and wireless equipment. A radio/TV broadcast certification is sponsored by the Society of Broadcast Engineers (SBE). It covers TV principles, as well as satellites and microwave. Technician and engineering level certifications are available. There is also a certification for cable TV technicians and engineers working for cable television companies. It is sponsored by the Society of Cable and Telecommunications Engineers (SCTE).

As you can see, there are lots of options, depending upon your communications specialty.

Preparing for the Exams

You don't have a prayer of passing these exams without some studying. The good news is that there are several sources of prep materials. The certifying organizations typically sell study guides that give complete details on exam content and even offer typical practice exams, including materials for FCC license prep. You can download the question list from the FCC as indicated earlier.

There are also various study guides or books you can buy. These are listed on the websites of the sponsoring organizations given in the Resources sidebar. When you go to the FCC website, look at the COLEM list and check with them for study materials, as well as exam service. Buy at least one, or as many as you can find, and go through them in detail. Another good investment is any practice exam that is available.

As you might expect, the contents of the FCC license and the more generic certification exams on communications are very similar. Generally speaking, if you study for one, you will essentially be ready to take any of the other exams. The differences are minor. So you should plan to get the FCC license, as well as at least one of the certifications. The combination will give you a killer one-two punch in applying for available communication jobs. As a first step, figure out what credentials you think will help you the most. Then go to the website of each organization and get the details about the certification options and the availability of study materials. Order what you need and wade in. You definitely won't complete your studies in one session, so plan to put in an hour or so each night until you get prepared.

A good tactic is to take any practice exam you can get first to see what you actually do know and don't know. Next, study those topics you need help on. Then take the same, or better still, another practice exam again. Do this until you make a passing grade. It is typically 75 percent, but check with each organization as the passing grade does vary.

The certifying organization will also tell you how to get in touch with those companies who give the exams. The FCC website designates the COLEMs which, as it turns out, are some of the certifying organizations. In most larger cities, you can take the exam locally. At worst, you may have to drive to a nearby city to take the exam. The cost of the exams vary, but occasionally run as high as $75.00, which is all the more reason to be prepared.

If you do not pass the first time, you will know coming out of the exam. Most of the exams are given on a PC and are automatically graded. If you do not pass, immediately debrief yourself to determine what you might have missed. As you take the exam, you will know or feel if you are answering correctly. But there are always a few questions that you are uneasy about or that you flat-out don't know. Make mental note of these. Then after the exam, write down specifically what you think you missed so you can study again.

After a specific period — usually 30 days or more — you can take the exam again. But you will have to pay the fee again and incur the travel time and costs, if necessary. Don't despair since your investment will eventually pay off. Trust me on this. It did for me earlier in my own career. Good luck. **NV**

RESOURCES

Consumer Electronics Association
www.ce.org/certifications
703-907-7600

Electronic Technicians Association International
www.eta-sda.com
800-288-3824

Federal Communications Commission
www.fcc.gov/commoperators/welcome.html
Complete information on all the FCC licenses, exams, COLEMs, etc.

International Society of Certified Electronic Technicians
www.iscet.org
817-921-9101

National Association of Radio and Telecommunications Engineers
www.narte.org
800-896-2783

Society of Broadcast Engineers
www.sbe.org
317-846-9000

Society of Cable Telecommunications Engineers
www.scte.org
800-542-5040

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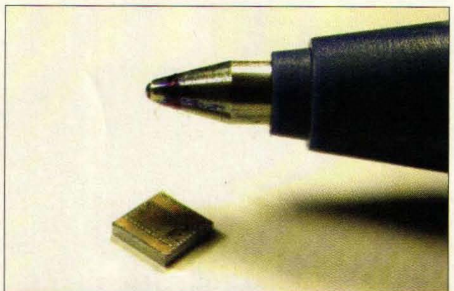
Advanced Technologies

Wireless Sensor Chip Measures Only Five Square Millimeters



UC Berkeley's "smart dust" chip combines RF communication and sensor processing in a 2 x 2.5 mm package. Photo by Jason Hill, courtesy of UC Berkeley.

Engineers at the University of California, Berkeley (**www.berkeley.edu**), have successfully tested a wireless sensor chip, named "Spec," that integrates sensors and transmitters on a platform that measures only five square millimeters. The device was developed as an element of the Smart Dust and TinyOS projects, which are part of UC Berkeley's Center for Information Technology Research in the Interest of Society (CITRIS).

The projects seek to create low-powered, low-cost wireless sensor devices, or "motes," roughly the size of a grain of sand. Large numbers of these millimeter-scaled motes — known as "smart dust" — could be used in self-organizing wireless sensor networks for such applications as monitoring seabird nests in remote habitats, pinpointing structural weaknesses in a building after an earthquake, and warning of the presence of biochemical toxins. The fundamental goal is to enable wireless sensor motes to talk to other nearby motes rather than pumping up the power of a single mote so that it can transmit through hundreds of feet of building space.

Spec combines a radio, an analog-to-digital converter, a temperature sensor, and the TinyOS operating system onto a 2 x 2.5 mm piece of silicon. Researchers who tested the new chip reported that it can transmit radio signals at 902 MHz over a distance of 40 feet (12.2 meters) at a rate of 19,200 kbps.

In its commercial form, Spec will be hundreds of times smaller than its predecessor, Mica — a mote that is available commercially through San Jose-based Crossbow Technology, Inc. (**www.xbow.com**). In addition to the chip, Spec requires an inductor, an antenna, a 32-kHz watch crystal, and a power source. These components are expected to add little to the size of the mote.

In addition to its potential for academic and consumer use, smart dust has generated interest from the military for its potential uses on the battlefield and to monitor troop movements. Two years ago, dozens of motes were dropped from an airplane alongside a road as a test. The matchbox-sized motes tracked the speed and direction of passing vehicles based on vibrations in the ground. According to a UC Berkeley representative, the product could be available commercially within the next year. The finished product, which will include the battery and casing, will likely be about the size of an aspirin.

Computers and Networking

New Wireless LAN Standard Adopted

A long-awaited standard for wireless LANs (Land Area Networks) that allows more carrying capacity than the current IEEE 802.11b specification, but uses the same frequencies, has won final approval. The new 802.11g standard lays out the ground rules for WLAN equipment that is capable of data rates of at least 24 Mbps, and up to 54 Mbps, while remaining backward compatible with existing 802.11b devices that run at a maximum of 11 Mbps. Both use radio spectrum in the 2.4 GHz band. The Standards Board of the Institute of Electrical and Electronics Engineers, Inc. (**www.ieee.org**), approved the new specification after a standardization process that took just over three years. Many vendors have already been shipping equipment based on drafts of the standard for months, and have said they will make those products meet the final specification through free firmware downloads. The draft products already are driving the growth of the WLAN business, which has been one of the few bright spots in a gloomy IT industry in recent years.

Desktop DC-Powered PC For Vehicles

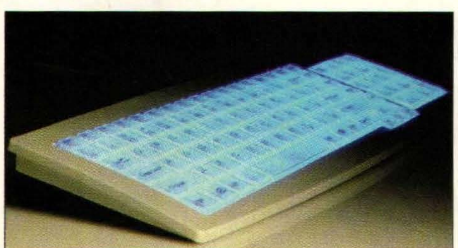
Monarch Computer Systems, Inc. (**www.monarchcomputer.com**), has created a new line of small-form-factor 12-VDC systems that target the home and mobile entertainment market. The Traveler line is designed for implementation in all types of vehicles, and it can be used as an MP3 player, DVD player, gaming console, CD-Burner, GPS system, and TV capture and video editing station in a mobile home, RV, boat, or car. Additionally, the design makes the system useful in kiosks, point-of-sale environments, presentations, and fixed-function applications where noise and size are greater considerations than raw processing power.

The machine is based on the VIA EPIA M10000 one-GHz Nehemiah motherboard/processor platform. It has 256 MB of PC2100 (266 MHz) DDR SDRAM, a 40-GB hard drive, 24X10X24 CD-RW combined with an 8X DVD-ROM, a floppy drive, a 10/100 Ethernet Adapter, four USB 2.0 ports, and one IEEE-1394 firewire port. The system can also be purchased with an optional DC Travel package containing two DC power adapters and a Y power adapter, an audio Y cable to adapt the system to RCA composite connectors, and industrial Velcro™ for mounting the system in vehicles. Additional options include a mobile GPS package, remote control, mini-keyboard with touch pad, a 15-inch LCD flat-panel monitor, and Microsoft Windows XP Home Edition Operating System.

The system base price is $589.00, but that is for the box alone. If you add Windows XP ($89.00), an LCD monitor ($254.00), the keyboard ($29.00), and the Travel package ($69.00), the price ratchets up to $1,030.00. The game pad will add another $45.00, and the remote costs $49.00. As of this writing, the unit is available only from Monarch, so don't look for it in your local computer shop.

Illuminated Keyboard For Dark And Poorly Lit Workspaces

If you live in a cave, monastery, or prison cell that has no window, or if you just spend a lot of time computing at night, you may sometimes find it difficult to see the keyboard. A solution is now available in the form of the EluminX illuminated keyboard from Auravision **www.auravisionllc.com**.

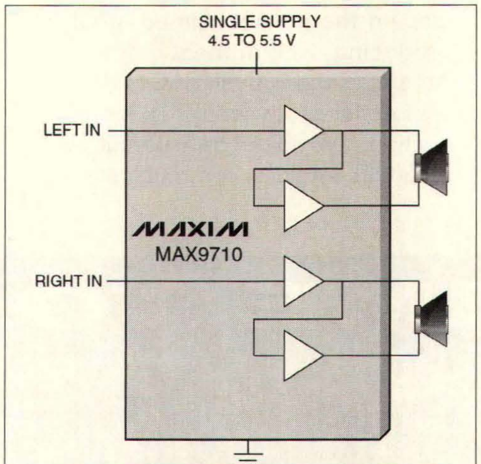


The EluminX™ illuminated keyboard from Auravision™ is a patented computer keyboard with internal luminescence.

According to the company, it is the first commercially-available computer keyboard with internal luminescence. The device uses electroluminescence technology, providing a choice of aquamarine or sapphire illumination. The case is available in black, bone, or silver. The Windows-compatible device (no Mac version offered) provides the standard 104 keys (12 function keys), a sleep function, and a one-year warranty. The only downside is the cost, which is about $99.00 on several computer store web sites.

Circuits and Devices

Mono/Stereo Amplifiers Offer Low Distortion



Simplified Block Diagram of the MAX9710 Three-Watt Amplifier. Courtesy of Maxim Integrated Products.

For project designs that require a compact audio amplifier, Maxim Integrated Products (**www.maxim-ic.com**) offers two new devices. The MAX9710 is a three-watt, stereophonic, bridge-tied-load (BTL) audio amp, and the MAX9711 is the monophonic version. These amplifiers operate from a single 4.5- to 5.5-volt supply and feature a 100 dB PSRR, allowing operation from noisy supplies without additional power supply conditioning. The low 0.005 percent THD+N is aimed at clean, low-distortion amplification of the audio signal, and patented click-and-pop suppression eliminates audible transients on power and shut-down cycles. Power-saving features include a 2-mV offset voltage to minimize DC-current drain through the speakers, a 7-mA supply current, and a 0.5-µA shut-down mode. A MUTE function allows the outputs to be quickly enabled or disabled.

The MAX9710 is available in thermally efficient 20-pin QFN (5 x 5 x 0.8 mm) or 16-pin TSSOP-EP (exposed pad) packages. The MAX9711 is available in a 12-pin QFN (4 x 4 x 0.8 mm) package. Both devices have complete thermal overload protection and are specified over the extended -40 to +85°C temperature range. Prices start at $0.55, but only in production quantities (100,000 or more). Individual units will be higher when they appear in your local electronics shop.

GPS Personal Locator Finds Children

For people who (1) are prone to losing their children and (2) can afford another expensive wireless service, Wherify Wireless, Inc. (**www.wherify.com**), has a new gadget. The Wherify Personal Locator for Children is a miniaturized watch-like device that you strap onto a child's wrist, enabling you to track and locate him any time of the day or night.

The operational concept is somewhat complex, although it is said to take less than 60 seconds to perform. To locate the missing loved one, you telephone the Location Service Center or log onto the corresponding web site. The Service Center contacts the child-borne device via a nationwide PCS network and requests a location. The Locator finds the best GPS satellites,

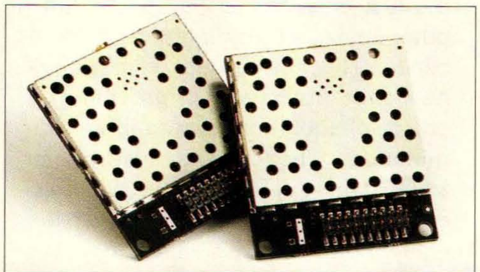
The Wherify Personal Locator uses GPS satellites to track a lost child within 60 seconds. Courtesy of Wherify Wireless, Inc.

computes coordinates, and determines the wearer's location. This information is then sent back to the Location Service Center and passed on to you. Drawbacks include the relatively substantial weight of the Locator (3.9 ounces, 110 grams) and the $399.00 price tag. Plus, the service costs from $25.00 to $35.00 per month. Battery life is only 48 hours in standby mode, which could be a limitation in some cases.

Wherify suggests that the device might also be used for Alzheimer and memory loss supervision, animal identification, property asset tracking, and other applications.

It is not immediately clear how one can keep a resourceful child from transferring the device to a friend, the family dog, or a passing wino, but perhaps the next-generation Locator will be small enough to be embedded directly in your child's skull, thus relieving you of even more parental responsibility.

Low-Cost 900 MHz RF Module Available



AeroComm's 900 MHz spread spectrum transceiver offers data rates up to 115.2 kbps. Courtesy of AeroComm, Inc.

AeroComm, Inc. (**www.aerocomm.com**), has introduced a new 900 MHz spread spectrum transceiver, with a price that is said to be half that of similarly specified modules on the market. Aimed at OEMs producing equipment for the Americas, the 900 MHz AC4490 module interfaces via serial TTL level connection, providing transparent, bidirectional wireless communication in point-to-point and point-to-multipoint, client/server, or peer-to-peer networks using AeroComm's proprietary RF232 transparent protocol. According to AeroComm, typical low-cost radios provide only RF transmission — they do not include a protocol to manage "over-the-air" issues such as how to overcome interference and multipath problems, detect errors in the data, address messages to individual radios, secure transmissions from eavesdropping, and verify link quality. RF232 handles these issues with the same protocol found in more expensive radios.

RF232 allows AC4490 modules to be used as direct cable replacements, requiring no special host software for communication. Communications include both system and configuration data. All frequency hopping, synchronization, and RF system data transmission/reception is performed by the transceiver. Plus, AC4490s feature a number of on-the-fly control commands, providing OEMs with a very versatile interface for any application.

Cited product enhancements include:

- Data rates up to 115.2 kbps.
- Small dimensions of 1.65 x 1.9 inches (42 x 48 mm).
- Output power variable from 5 to 500 mW.
- Adjustable receiver sensitivity from -96 dB, depending on data throughput.
- A variety of antenna options.

The unit is priced at less than $30.00 in quantities of 10,000 units.

Industry and the Profession

Digital AM Radio Is Coming

You probably don't spend much time tuned to the AM radio band anymore, but that could change in coming years. Back in June, the Digital Radio Mondiale (DRM) consortium (**www.drm.org**) agreed to pursue a technology that can bring FM-like sound quality and improved reception conditions in the long, short, and mid-range wave frequency bands. The DRM consortium includes 70+ members, including service providers such as the BBC, Radio France International, Voice of America, and others. Also represented are equipment manufacturers including Sony, Hitachi, Dolby Labs, and Bosch.

In addition to improved sound, the technology will allow the transmission of text information such as stock quotes and traffic messages, plus information about the radio station, the title of the recording, the artist's name, and so on.

Other user benefits include lower cost for receivers, lower battery consumption, more diverse program content, and a wider receiver range. Equipment manufacturers, of course, hope to sell receivers that will replace the estimated 2.5 billion radios already in existence. Plus, the technology promises enormous energy savings to broadcasters.

The concept applies new modulation processes such as coded orthogonal frequency division multiplexing (COFDM), but the biggest difference is in the upgraded coding process for data compression. The technique is essentially an extension of MP3 technology called aacPlus. It is said to deliver CD-quality sound at a data rate of only 48 kbps.

Before you will be able to buy a receiver, however, equipment manufacturers need to adopt the technology and bring systems to market. A complete conversion is expected to take a decade. The International Electrotechnical Commission (IEC) now recognizes the DRM technique in an international standard. For details, you can buy a copy of standard IEC 62272-1 Ed. 1: Digital Radio Mondiale (DRM) — Part 1: System Specification from the IEC (**www.iec.ch**) for 260 Swiss francs. **NV**

Understanding, Designing, and Constructing Robots & Robotic Systems

Amateur Robotics

Getting Started In Combat Robots — Part 3

Last month, we figured out what kind of wheels to use on this project. We took a look at the different speed controllers on the market and chose one. I picked a type of battery for its current capability. I chose a type of frame, picked out a workable material, and started building it. Now on to armor and electronics.

Armor

The armor I chose was a little expensive, but I wanted it to be good looking, as well as effective. I picked up some 1/8 inch thick, polished aluminum diamond plate at the local hardware store. It came in different sizes. The piece I chose was 12 inches wide and 24 inches long.

I cut this to form the top and bottom armor. I used a press brake to put a one-inch lip on one side so that it folded over onto the back of the wedge. This would give me a place to mount the rear sheet of polycarbonate armor. It also left about 1-1/2 inches of open space on both sides of the tip of the wedge.

Even in a light bot, there are certain things you should include when designing the frame, mounting the electronics, and including armor. Mounting the motors and aluminum armor has incorporated support structure for the frame. Now we'll add some real armor that helps protect the frame and electronics.

Titanium is probably the best thing you can buy for armor. It is much lighter than steel, yet stronger at the same time. Where steel breaks or rips, titanium will flex and spring back into position. Carbon fiber panels are also a good bet for protection.

There is a web site that sells parts for one pound bots called **www.SozBots.com**. The "Soz" stands for 16 ounces. You can buy a 6-inch x 9-inch x 0.032-inch sheet of grade 5 titanium there for about $19.00. This is excellent material for covering the open spaces on the nose of the wedge.

I bent the titanium on a press brake after using a torch to heat it up. Do not try to bend titanium without heating it. It is brittle enough to break if you push it far enough. Also, remember to drill any mounting holes in the sheet before you bend it.

I also picked up a sheet of carbon fiber at SozBots. It is about twice as thick as the titanium and has the same length and width. I used this material to create a motherboard for the bot's electronics.

I first placed all the electronics on the board. After drilling holes for mounting, I used large zip ties and double-sided tape to hold the components down. Since everything is relatively light, I think ties should be okay. The battery pack is the heaviest thing so I used several to hold it down.

Figure 2. Titanium Armor. Part A shows the titanium in its original shape. Part B shows the titanium after bending. When bending this metal, heat it with an oxy/acetylene torch in a straight line until red hot. The material is so thin that it will warp. While it is red, use a press brake to bend it into the shape of the tip of the wedge. Do not let it cool before bending or it will snap. The press brake will also flatten the warp.

Figure 1. Stick Frame of Wedge Bot. Shows the aluminum "C" channel and armor riveted together. The motors and rear, hinged door are in place, too. Materials purchased at the local hardware store.

Electronics

Once the parts were mounted on the motherboard, I wired up the system. Figure 3 shows the connections between the receiver, the mixer, the speed controllers, the batteries, and the motors. The speed controllers come with a power switch and a battery eliminator circuit (BEC) for the receiver. Notice that the power wire from ESC1 is not connected to the mixer.

Normally, a separate battery pack supplies power to the receiver and any servos connected to it. Since the BEC is included in the speed controller, the receiver gets its power from there. You only need one source of power from the two ESCs, so you should not connect the second line. You do still need the ground and signal wires.

Once the motherboard is assembled, you can mount it in the bot. I suggest that you find some small rubber vibration dampers and use them. I hot-glued some mousepad bits to the carbon fiber board. After that, I secured the motherboard to the frame and armor with small bolts.

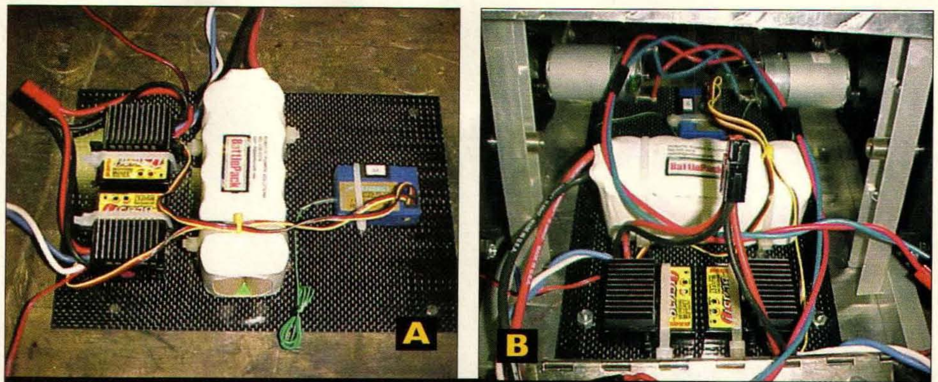


Figure 4. Motherboard. Part A shows the assembled motherboard for the bot. Part B shows the motherboard mounted inside the bot.

Last Steps

The last part of construction involves closing up the back end of the wedge. Both pieces of aluminum diamond plate armor have a one-inch lip bent into them. I mounted some small, stainless steel hinges to the bottom. On the other half of the hinges I mounted a 1/8-inch thick polycarbonate, bullet resistant glass door. You will have to get inside the bot to charge the batteries or fix problems. I used several self-tapping screws to hold the free side of the door in place.

Now I have a finished bot. It is two-wheel drive and the nose of the wedge drags on the floor in order to get under its opponent. The nose is made from titanium and the main wedge armor is diamond plate aluminum. The rear end gives the bot a cool, see-through effect, while at the same time protects the vital organs. The wheels are large enough and strong enough to protect the sides of the bot from attack.

They also extend past the bot's edges so that no opponent can tip the front end and disable us by leaving the bot on its back. There is one fault in the design. If an opponent lifts us just the right amount, our wheels will be off the ground. In my future designs, I'll end up cutting the corners of the cheese wedge to avoid this problem.

Common Failures

The most common failure points of a combat robot fall into about four main categories. The "parts that are not used correctly" category includes speed controllers, batteries, motors, and gears that are expected to do more than their designated ratings allow.

If a motor, battery, or speed controller is too weak, it is too weak. Do the math — and do not expect it to pull the weight if the numbers do not match.

The "parts that are not mounted correctly" category includes everything that you bolt, strap, tie, or use bubble gum to stick to the walls of the robot. Bolts should be used with thread locking solution and should be checked for tightness after each match. Major components should have no possible way to come loose and flop around.

The "parts that are not reliable" category includes home-built electronic components and improper remote control antennas, among other things. If you know that your tires can be punctured and cause a problem, use solid or foam-filled tires.

The last category, "bad design," can be helped only by experience. If you need ground clearance to compete, make sure you have enough. Things like that will make you smack your forehead. Pay attention to all four categories, and you will have a much better chance at winning something.

Test Drive

You should spend lots of time driving your bot. Of course, you can only practice driving your bot if you finish building it before the competition. There are several types of driving practice. You should get proficient at all of them.

The first kind of practice you should get is meant to get you used to how the bot moves. You have to get used to its speed, turning ability, aiming ability, and stopping ability. Smaller bots can be driven around in

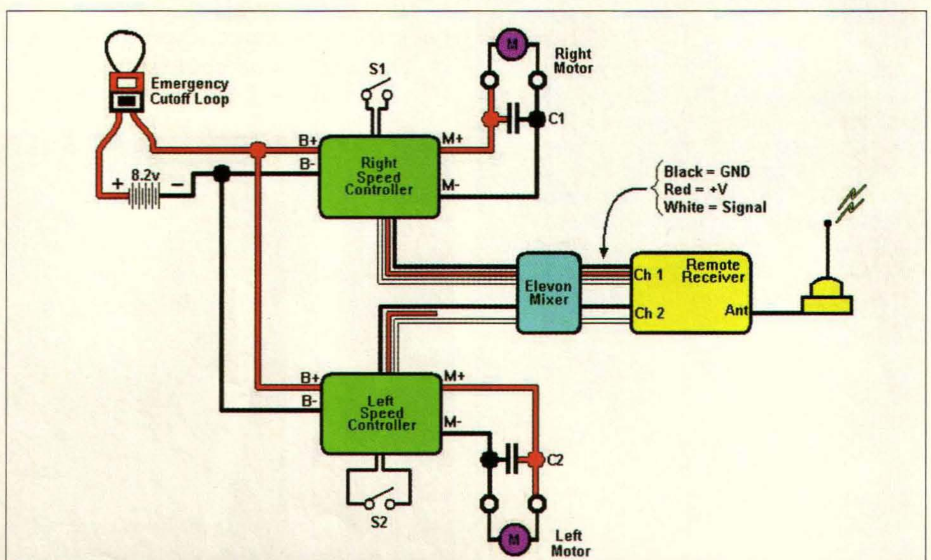


Figure 3. Bot Schematic. Shows the simple block-diagram schematic of the wedge bot. Note that the power line to the receiver from one of the ESCs is not connected. This is because the receiver gets its power from the other ESC's battery eliminator circuit.

Figure 6. NCRSF Banner. I organize an event for bots ranging from 12 pounds to 340 pounds. Live events such as this and those listed at the RFL web site are a great place to break into combat robotics.

a carport or on a cement driveway. Larger bots need to practice in an empty parking lot.

Practice driving away, returning, and driving side-to-side. Spend time doing lots of turns and spins. Do some 90° and 180° turns. Challenge a brick wall. Don't slam into it but charge straight at it and hit the brakes. See how close you can come to it without making contact. If you hit and something breaks, it wasn't strong enough in the first place.

Once you get the hang of driving your bot, it is time to add some obstacles. In a real competition, there will likely be some type of obstacle in the arena that you want to avoid. Whether it's saws in the floor or flame pits, you want to avoid them. Use traffic cones to set up a driving course.

Practice driving the course while standing in different spots. Start pushing a cardboard box around the course. If you have a heavier bot, use an old tire instead. Once you get good at that, try pushing a basketball through the course. It will get away from you easily. When you finally get good at that, try pushing a football around.

All of this practice is getting you used to driving your bot. You need some dog-fighting experience, too. You can either build a second bot and practice fighting in the driveway or parking lot, or simply get a cheap R/C car to chase around.

Competition

After spending a few million hours practicing (yeah right!), it's time to enter a real competition. Next to building a bot, going to competitions has to be the best pastime ever. I mentioned the Robot Fighting League (**www.botleague.com**) earlier in the article. There are currently more than 20 different member organizations in the RFL. The North Carolina Robot StreetFight (**www.NCRSF.com**) is one of the charter members, and just happens to be the competition that I organize.

Every year, I host one or two large events that allow six weight classes, starting at 12 pounds and going up to 340 pounds. Builders come in from as far north as New Hampshire, as far south as Florida, and as far west as Ohio to fight their bots in a 32-foot square arena.

If you pay attention to the following three things, you will have a great time while at a competition.

Make sure you plan your budget correctly. If you are traveling, include money for airfare, hotels, rental cars, shipping, food, bot parts, and souvenirs.

After budget, tools and equipment are the next things that should be kept in mind. You should mark your tools with colored tape or paint to help you identify what is yours. The atmosphere in the pit area has been such that you can borrow anything as long as you return it.

Bring it back as soon as you finish and in better shape than you got it. Get to know your pit neighbors. They will watch out for your stuff, too.

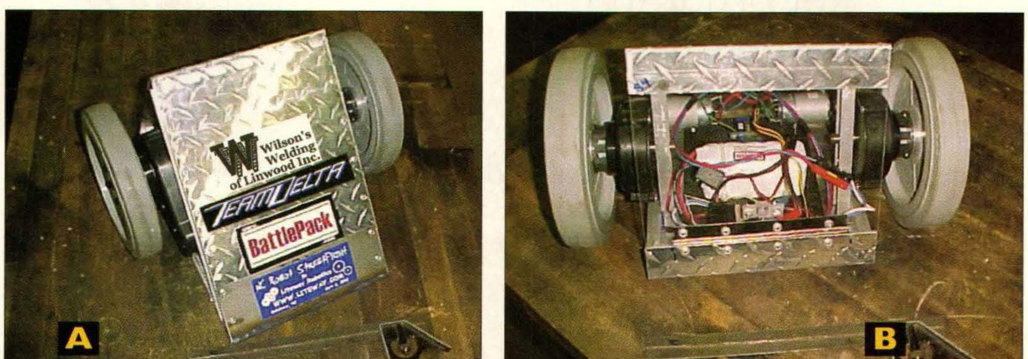


Figure 5. Finished Bot. Part A shows the front of the bot with titanium armor and sponsor stickers installed. Part B shows the rear of the bot with the polycarbonate cover in place. The carpenter's square is for scale. It is 12 inches long.

The last thing to keep in mind is pit area safety. Keep all electric tools unplugged when not in use and keep all sharp things on the bot and in the pit area covered. The pit area is typically very crowded. Try to keep your area clean and clear. Keep your safety and the safety of the people around you at a high priority.

Weapons

If you've taken my advice and built a simple wedge to get started, you will soon feel the need to include something that can cause some real damage to your opponent. There are lots of weapon types to choose from. Spinners are probably the most dangerous to their opponents. Bot weapons powered by IC engines or pneumatics are probably the most dangerous to their builders.

There are several types of weapon systems including the spinners, lifters, overhead attack, the pneumatic spears, and the clamping bots. Each one has opponents that it should do well against. Each one has opponents that it won't do well against.

The best things to do are build something that interests you and get lots of driving practice. Practice is what will make you successful in the arena. In the end, it's all about fun, learning, and safety.

If you really want to know about all the different types of weapons, it might pay for you to get my book *Combat Robot Weapons*. It is published by McGraw Hill and discusses the pros and cons and gives building technique tips for just about every existing weapon known to combat robots.

Summary

Over the course of the last three months, I've presented you with some invaluable information about combat robots. I came up with a strategy, a bot style, and a design to accomplish it. We picked the components and put them all together to form a working bot. I even gave you the secret to winning ... driving practice.

There is a ton of information on the Internet that you will find useful. Like I mentioned before, I even have two books out on the subject. You can find them at **Amazon.com**. I hope you find them and this article helpful. So stay safe and I'll see you at the next competition. **NV**

Last month when talking about batteries, I said that you should wire your packs in series so that they share the current requirements. That is wrong, of course. I meant to say that you should wire them in *parallel* in order to share the burden of the current requirements. Wiring in series will give you more voltage. If you wire two 12-volt packs in series, the pair will yield 24 volts. Wire two 12-volt packs in series and they will source about 160 amps. Thank you to a reader for pointing this out. (Unfortunately I lost his email, so I don't know his name.)

Circle #42 on the Reader Service Card.

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:

More applications for the disposable camera flash. Getting started with PICs. Circuits of the month: turntable preamp, pink noise filter, and a zero-crossing detector. Finally, a look at the summer sky.

Disposable Camera Slave Flash

Q. I have three disposable cameras that I've taken apart to use as remote slave strobes. I want these units to synchronously flash off the flash of my camera — a light trigger, so to speak. Could I use a photodiode to do this? All it needs to do is close a switch, I think.

Cousingrace
via Internet

A. You are correct in assuming that all you need to do is close a switch. Unfortunately, there are 300 volts across that switch — far in excess of what a photodiode can handle. A better choice is to interface the photodiode to an SCR, which can handle the voltage and provide a clean connection. However, trying to trigger an SCR directly from a photodiode is an iffy and unstable proposition. So what I did was insert a 555 one-shot circuit between a phototransistor and the SCR — a very stable combination (Figure 1). A 555 was selected because it contains a comparator-triggered flip-flop that provided a clean snap that the SCR gate requires.

Before you ask, the answer is yes, I experimented with logic gates, but they didn't have the clean snap of the 555. Often the logic gate would rest in an "analog" region between on and off, or the rise time would be too slow to keep in step with the master strobe. Hence, the 555. The sensitivity control is used to balance the ambient light with that of the strobe flash for reliable operation.

Disposable Camera Flash Battery Eliminator

Q. I have converted a Kodak Max camera into a strobe unit, and it works great. Unfortunately, it eats AA alkaline batteries like kids eat candy. I would like to power this unit from a 12-volt car battery. What kind of a circuit would it take to put out 1.5 volts at one to three amps?

Al Palmer
via Internet

A. It all depends on how much space you have and how much you want to spend. The simplest and least expensive solution is to use an LM350 linear regulator. The circuit in Figure 2 (shown on the right) uses just five components and costs about $5.00 to build — not counting the heatsink, which is absolutely necessary. At one amp, the regulator will dissipate 12 watts, at 3A it's 36 watts. Just visualize how hot a 25W light bulb gets and work from there.

A better solution is to use a switching buck regulator, like the LT1767 (shown in the schematic on the left). It runs cooler, but requires more parts and is limited to just 1.2 amps (which should be plenty for your strobe application). Notice that

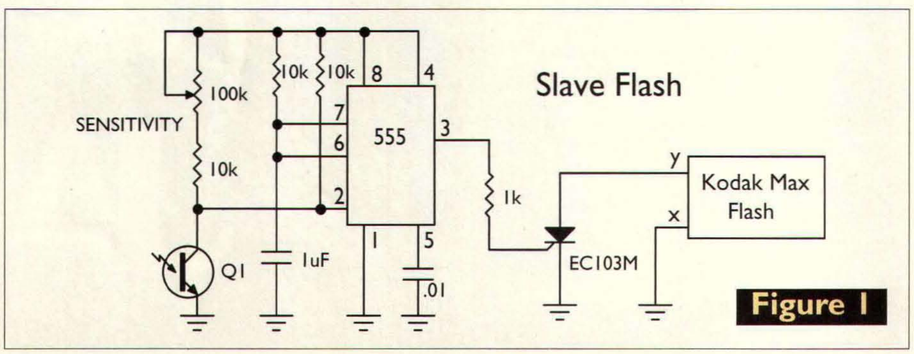
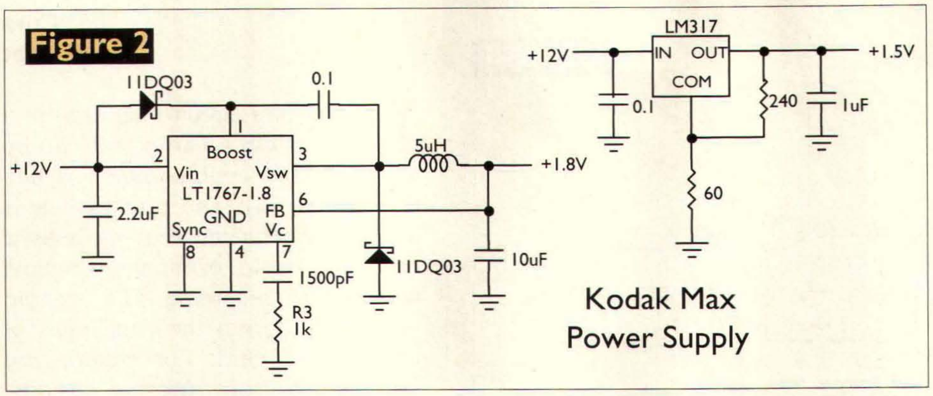


Figure 1

Figure 2



Kodak Max Power Supply

I've specified the 1.8-volt version of this regulator for this design, which will give your strobe an extra punch. The original design calls for all surface-mount devices (**www.linear.com/pdf/1767fas.pdf**), which leads to a very small design, but feel free to use standard leaded devices. Just keep in mind that the circuit operates at 1.25 MHz, so be sure to use short leads and good quality capacitors — ceramic are preferred.

KVMs Don't Have To Break The Bank

Q. To free up valuable desk space, I am trying to build a console switch so that my two PCs can use a single monitor, keyboard, and mouse. I remember there was a 4066 chip that might do the job, but found out later that it is discontinued. Is there other "analog switch" chip out there that will do the job, or do you have a better way of doing this, short of buying a $300.00 console switch?

Charles
via Internet

A. Well, there's more to it than simply switching between the two PCs. For one thing, you need mouse and keyboard emulators connected to the "idle" PC to keep it from crashing, and that allows it to perform a normal boot or reboot sequence. This is generally done using microcontrollers, usually a PIC or BASIC Stamp. Another bottleneck is a smooth transition of the monitor between PCs, which requires very high-frequency switches. Instead of building, I'd use a commercial KVM, like the VIP-702-KMV ($129.00) from Vetra (**www.vetra.com/Switch2.htm**). BTW, the 4066 is alive and well, but not for this application.

PIC Microcontroller Basics

Q. I'm a beginner to electronics and would like to get into PIC microcontrollers, but have a few questions.

1. Should I program them in Basic, which I know, or should I learn C language for the PIC programming?

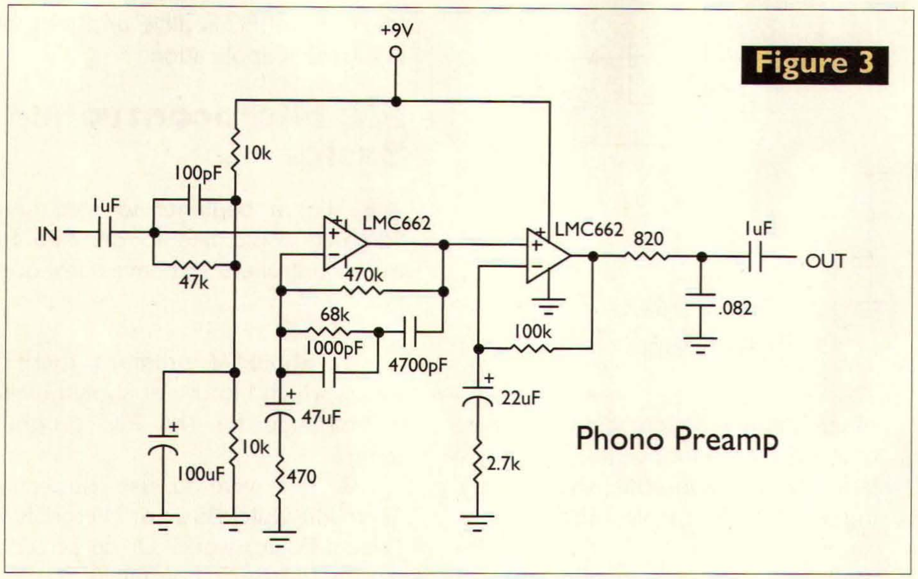
2. If I were to use Basic, will Microsoft QuickBasic or Microsoft VB (Visual Basic) work? Or do I need to get the PIC Basic compiler?

3. If you think I should use C, what do I need in the way of hardware and software to program the PIC, and will Visual C work as the compiler?

Anonymous
via Internet

A. That's quite a list of "I don't knows." Let's first straighten out the language choices. Basic is the simplest language to use, and the fact that you already know it is a plus. The most popular is PBasic (about $99.00) and includes a compiler.

C is a much harder language to learn and use. If you choose C language, you will have to buy the soft-



Curt
via Internet

A. Here is a circuit built around a dual CMOS op-amp that can be powered from a single nine-volt battery (Figure 3). The preamplifier is RIAA compensated and includes a rumble filter to eliminate turntable noise in the recording. The preamp output plugs into the Aux input of your sound card. For stereo, you need two of these circuits. Depending on your construction skills, the preamp can be reduced to about the size of a BIC lighter using the SOIC surface mount version of the chip and lithium cells.

When transferring the music, make sure your new CDs are compatible with your car player. If not, you may be disappointed. If you're in doubt, compare the formats listed in your PC burner and car player owner's manuals and choose the format they share in common (MP3 is a likely candidate).

ware (Visual C is fine), which isn't always cheap, plus acquire a PIC compiler. Microchip offers a C compiler for free, but only for the PIC17xxx and PIC18xxx families. Commercial C compilers for PICs run about $80.00. Moreover, C programming is overkill for all but the most ambitious PIC projects.

My preference is assembly language. I like it because it produces the tightest code — an important consideration when you only have 1K of program space to work with, and is fairly easy to learn. There are only 33 commands. Best of all, both the code and compiler are free.

Once you have decided on a language, then you need a PIC programmer or burner. This takes the compiled hex code and transfers it into the memory of the PIC. There are several on the market, ranging in price from $20.00 to over $100.00. Just make sure that the programmer you buy supports the PIC you intend to use, because each PIC requires a different starting sequence. CCS offers a low-cost C compiler that's easy to use with lots of example programs. More information can be found at **www.ccsinfo.com/picc**.

Phono Preamplifier

Q. I have quite a few very old phono records that I'd like to record to CDs so I can play them in my car. Can you suggest an inexpensive IC module that I can use to construct a miniature stereo preamp to boost the signal from a magnetic phono cartridge to a level suitable for input to my computer sound card?

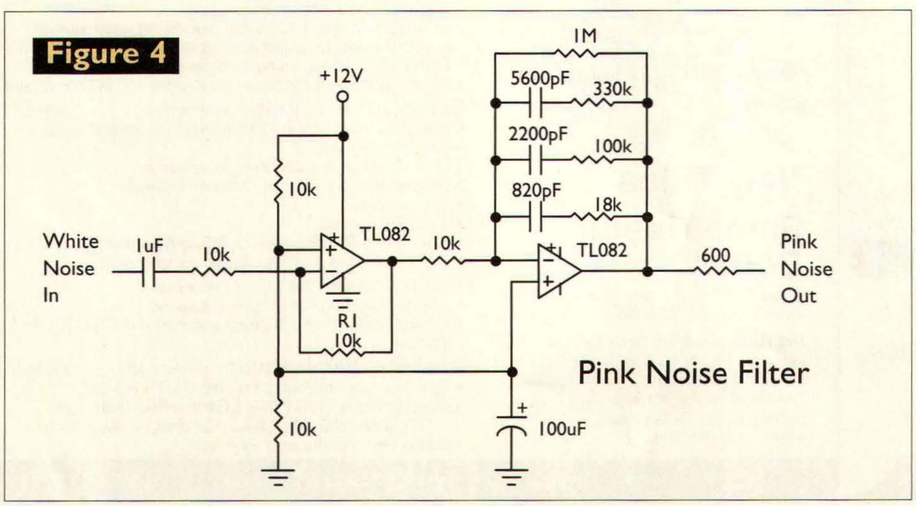
Pink Noise Filter

Q. I have a white noise generator and would like to add a filter on its output (zero to one volt, 600 ohms, unbalanced) to provide a pink noise signal. I believe I need a network to give a three dB per octave roll-off. Can you help me to design such a network?

Bill Woods
via Internet

A. White noise — the sound you hear when a TV is tuned to a non-existent station — has a frequency characteristic which raises the power level by 3dB with each increasing octave. By contrast, pink noise is characterized by a uniform power level across all frequencies. For example, the power level in the 40 Hz to 80 Hz octave is exactly the same as in the octave 10 kHz to 20 kHz. For audio testing, a pink noise source will quickly show any anomalies in speaker systems, room acoustics, and crossover networks.

By filtering a white noise source with a 3dB/octave filter, you can cre-



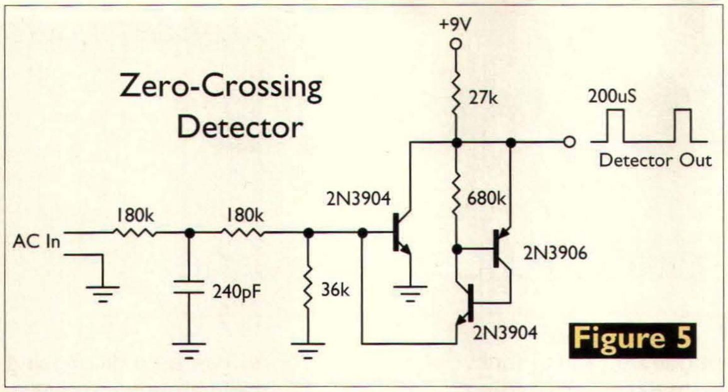


Figure 5

ate a very good approximation of pink noise. The circuit in Figure 4 is such a filter. The gain of the input op-amp is unity (Vin = Vout). You can adjust the gain as needed by increasing the value of R1 using the formula gain = R1/10k.

Zero-Crossing Detector

Q. I have a rotating magnet that generates a two-phase, 100-Hz signal at 35 volts. What I need is a circuit that produces a pulse each time phase one makes a zero crossing. (At this point, the phase 2 sinewave is at its peak.) I designed such a circuit about 25 years ago using NAND gates that has served me well — until lately, when it died. Unfortunately, the semiconductors I used are no longer available, so I can't repair or replace the circuit. I'm hoping you have an updated design.

Neil Curry
N. Hollywood, CA

A. I have a popular design (as in I didn't create it myself) that's often used in commercial equipment as a zero-crossing detector. The circuit uses just three inexpensive transistors and a handful of passive parts (Figure 5). Basically, the detector is a pulse generator that is triggered by a zero-voltage input. The input RC network acts as both a voltage divider (attenuator) and filter. For the values shown, the output pulse is 200 microseconds wide.

MAILBAG

Dear TJ:

In looking over the schematic for the cooling fan control circuit that you provided in the June 2002 issue, I noticed that you have the values for R1 and R2 as 75K and 1K. When I tried to design a similar circuit using the Excel spreadsheet that is available on Microchip's web site for the TC642 controller, I couldn't see how those values worked in this application.

Mike
via Internet

Response: I took those values from page 12 of the TC642 datasheet that I had at the time. After you questioned the values, I downloaded the revised TC642 datasheet from the Microchip web site, and guess what?! R1 is now listed as 20.5k and R2 has become 3.83k. Apparently, I'm not the only one who makes mistakes. Thanks for pointing this out.

TJ Byers
Q&A Editor

Dear TJ:

Regarding your reader's question in the May 2003 issue (12-Volt Hum Filter), I also live in a travel trailer for about 4–8 months out of the year (in Iowa no less) and have found that the battery charger is just that — a battery charger. It should not be considered a stand-alone DC supply; it's the battery that provides the filtering. I would bet that the storage battery in Kenny's trailer is either dead, dry, or missing. Simply replacing it with a good battery should cure his hum problems.

E. Paul Alciatore III
Fairfield, IA

Cool Web Sites!

Wonder where to find Jupiter or Mars in the night sky? Visit The Planets This Week web site for the answer.
www.skytonight.org/ieplanets.html

The Nine Planets: A multimedia tour of the solar system
http://seds.lpl.arizona.edu/nineplanets/nineplanets/nineplanets.html

Exploring the Planets: A gallery of planetary history and exploration. Sponsored by the National Air and Space Museum.
www.nasm.si.edu/ceps/etp/etp.htm

Basics For Beginners

Just For Starters

Learning Your Way Around Audio Equipment

Many beginners cut their teeth on audio equipment. They begin to learn on their church sound system or with band equipment. So, let's take a quick look at some audio basics.

Microphones come in two basic types, as far as cabling is concerned. Low impedance mikes are balanced, meaning you have two conductors and a separate ground shield. High impedance mikes are unbalanced, meaning you have one conductor and a ground shield. A low impedance mike can be connected to a high impedance input with only a loss in volume. However, a high impedance mike connected to a low impedance input will exhibit a very altered response pattern and will sound "tinny."

The output of a CD player, tuner, etc., is generally going to be in the range of -10 to zero dB. You can get away with things at this level that would create tremendous noise at the level of microphones. Microphones generally have an output in the range of -40 to -50 dB. This extremely small output level means microphones are much more susceptible to noise pick-up. We will discuss the dB in another column. For now, just note that the microphone output is much, much less. Your better, more expensive microphones are all low impedance. Two conductors and a shield give you more noise protection. The twisted pair inside the cable provides a noise canceling effect, and the entire circuit is floating above ground in a closed loop. Noise signals in the air are seeking a return to ground. Because you have a closed loop above ground, the balanced circuit provides no ground return for these interfering signals. Computers, florescent lights, copy machines, and many other devices give off radiated noise that is looking for a ground return. An AM radio tuned to a blank spot will show you how much noise pollution we have today. So again, because the unbalanced circuit provides no ground return, it is less susceptible to this noise. Another important factor in audio is the cable itself. Using the proper cable can make all the difference in the world. Microphone cable has distinct features that make it work. Ordinary cabling for high level (zero dB and above) signals has less shielding and is not flexible like mike cable. Any cable that is designed to be moved around will have fabric in the construction to allow the conductors and the shield to move within the cable as the cable is twisted and moved about.

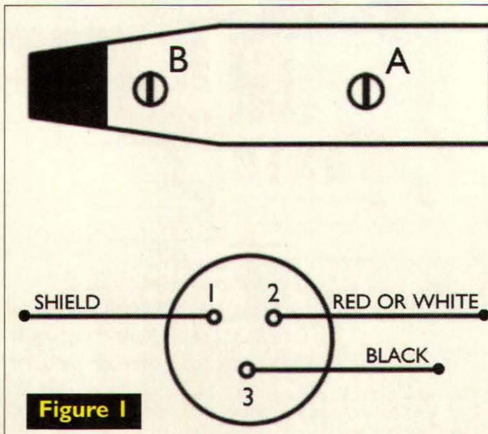


Figure 1

Now, let's look at how to wire a mike plug. There are several different manufacturers of mike plugs and the cases come apart in different ways. However, for our example, we will use the A3 plug. When wiring a plug, the pin configuration is the same, regardless of manufacturer. The only difference is how the case comes apart. Removing an A3-type mike plug cover can be a distressing and frustrating event until you realize that, in order to remove the cover, it is necessary to move the screw *in* not *out*. To remove the cover, turn screw (A) counterclockwise. It moves down, out of the way, and the cover will slide off. Be sure to loosen your cable clamping screws (B) until they are almost out. See Figure 1.

When wiring a mike plug, if you follow this layout, you will probably match whatever it is to mate with. I have found that 99.9 percent of the equipment I have worked with has had the following pin connections: pin 1 is ground (shield), pin 2 is positive (color), and pin 3 is negative (black). Fill the pin cups with solder and "tin" the wires. Then you only have to heat them to put them together. Heat the pin until the solder melts and just insert the wire.

Pins 2 and 3 can be reversed without hurting anything unless you are using two mikes close together. Then you will get phase cancellation. This is evidenced by mike #1 dropping in level when mike #2 is turned on. Either mike will have a higher volume level when it is on by itself than it does when they are both on. If you have this situation, all you have to do is reverse the wires on pins 2 and 3 of *one end* of *one* of the mike cables.

If you follow the wiring layout shown for all of your mikes, you should never encounter this problem. However, you need to be aware of the symptoms and be able to recognize the problem and correct it.

If the shield is broken, or on the wrong pin, the mike will probably still work to some degree. But, you will have hum, usually louder as you move your hand toward the mike. If a wire on #2 or #3 breaks, the mike won't work at all. **NV**

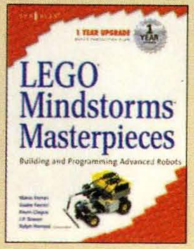
Circle #35 on the Reader Service Card.

Selected Titles for the Electronics Hobbyist and Technician—

The Nuts & Volts Hobbyist Bookstore

Robotics

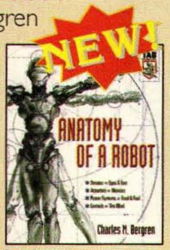
LEGO Mindstorms Masterpieces: Building and Programming Advanced Robots



While many LEGO books exist that show step-by-step instructions, they lack substantially detailed explanations about the building techniques used by the builders and the general concepts that are fundamental to the projects. These reflections are the foundation of LEGO MINDSTORMS Masterpieces. The goal of this book is to present very sophisticated projects with the maximum level of detail. In the book, you will find not only high-quality step-by-step instructions for building all of the robots, but also a complete description for each of them, including goals, building techniques, programming techniques, and the theory supporting the designer's choices. ***$49.95***

Anatomy of a Robot

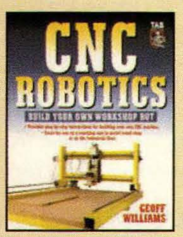
by Charles Bergren



Discover how robots articulate movements, how they see and hear, what gives them their power, and, at times, their gentleness. Delve into the robot's "brains," and learn how experienced robot designers use control systems to make their machines think. Much more than an enumeration of parts, Anatomy of a Robot exposes the life and human creativity behind today's robot. Always entertaining, this exceptional book takes you deep inside the theory and craft, philosophy, and science of robotics. **$29.95**

CNC Robotics

by Geoff Williams



CNC Robotics gives you step-by-step illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80 percent of the price of an off-the-shelf bot — and that can be customized to suit your purposes exactly, because you designed it. Written by an accomplished workshop bot designer/builder. **$34.95**

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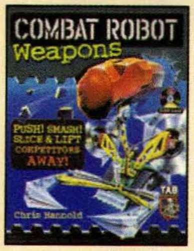
Combat Robot Weapons

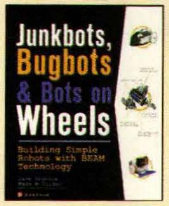
by Chris Hannold *New!*



Build combat robots that smash, slash, and pummel their way to victory with McGraw-Hill's Combat Robot Weapons. Including detailed information on weapon construction, fight strategy, and tips from combat robot guru Chris Hannold, this practical guide delivers everything you need to know to add a wide variety of weapons to your robots. **$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

New!

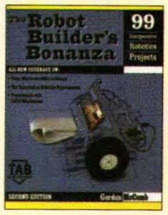
This essential title is just what robotics hobbyists need to build an effective drive train using inexpensive, off-the-shelf parts. Leaving heavy-duty "tech speak" behind, the authors focus on the actual concepts and applications necessary to build — and understand — these critical force-conveying systems.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

The Robot Builder's Bonanza

by Gordon McComb

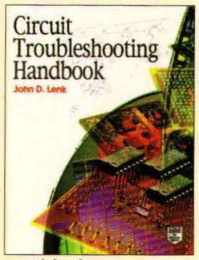


A major revision of the bestselling "bible" of amateur robotics building — packed with the latest in servo motor technology, microcontrolled robots, remote control, Lego Mindstorms Kits, and other commercial kits. **$24.95**

Troubleshooting

Circuit Troubleshooting Handbook

by John D. Lenk

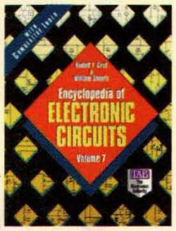


When it comes to troubleshooting, no other book even comes close — hundreds of circuits are covered in this exhaustive handbook. Heavily illustrated with diagrams and schematics, it uses an easy-to-follow format to help readers understand and troubleshoot a wide range of circuit types, and provides proven 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 *Sixth Edition*

by William B. Ribbens

This new edition explains electronically controlled (EC) vehicle motion control systems including advanced suspension, electric power steering, 4-wheel steering and electric brakes. The braking systems are part of an integrated motion control system that couples ABS brakes, traction control, and variable vehicle dynamics for enhanced stability. Also covers the development of hybrid/electric vehicles. **$39.99**

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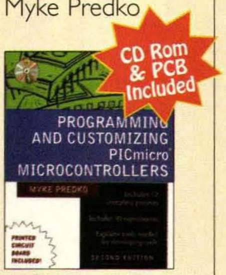
Microcontrollers

Programming & Customizing the HC11 Microcontroller
by Tom Fox

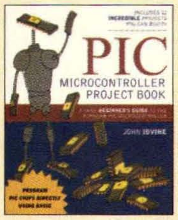
Applications bazaar for the 68HC11 microcontroller. Squeeze every drop of power out of Motorola's wildly popular family of 68HC11 true 8-bit single chip computers! From basics to complete applications. **$39.95**

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 and Customizing the OOPic Microcontroller
by Dennis Clark *NEW!*

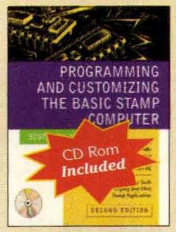
If you're a robotics professional or hobbyist, here's the one book you'll need to keep your work on the leading edge — Programming and Customizing the OOPic Microcontroller. This is the official OOPic Handbook, fully endorsed by Savage Innovations, the world's only manufacturer of OOPic microcontrollers. As the first book of its kind, this volume is destined to become the standard against which all other OOPic books will be judged. **$39.95**

Don't forget to order your charter subscription to ***Servo Magazine***. Details are on page 20.

Programming & Customizing the 8051 Microcontroller
by Myke Predko

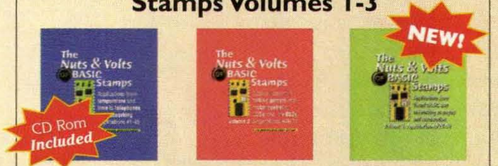
Programming and Customizing the 8051 Microcontroller puts you in control of the 8051's architecture and instruction set — and even supplies a baker's dozen of ready-to-build example applications, programs, and circuits. Best of all, the included CD-ROM supplies source code for the book's experiments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

The Nuts & Volts of BASIC Stamps Volumes 1-3



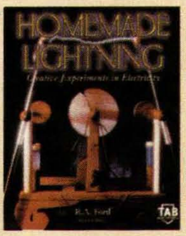
$49.95 Volumes 1&2 | **$69.95** all 3 volumes | **$29.95** Volume 3

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!

High Voltage

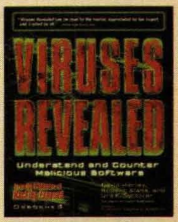
Homemade Lightning: Creative Experiments in Electricity
by R.A. Ford



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**

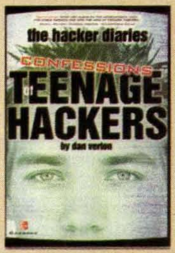
Computer Hacking

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



This detailed guide offers full-scale coverage and analysis of the origin, structure, and technology behind computer viruses, and addresses current methods of detection and prevention. By learning exactly how viruses do what they do, you'll better understand how anti-malware technology works — and be able to evaluate and implement practical solutions to protect your system. You'll get insight into the various types of malicious software — including Trojan horses, macro viruses, and worms — and also learn about virus hoaxes. **$39.99**

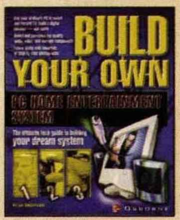
The Hacker Diaries: Confessions of Teenage Hackers
by Dan Verton



Through fascinating interviews with FBI agents, criminal psychologists, law-enforcement officials — as well as current and former hackers — you'll get a glimpse inside the mind of today's teenage hacker. Learn how they think and understand the internal and external pressures that pushed them deeper and deeper into the hacker underground. **$24.99**

Home Entertainment

Build Your Own PC Home Entertainment System
by Brian Underdahl



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**

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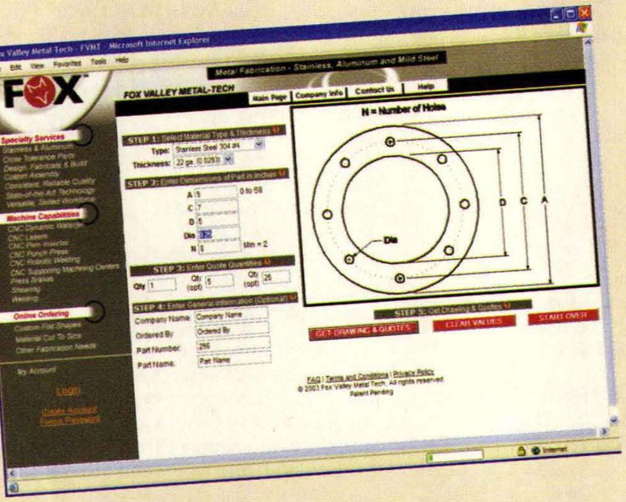
E-COMMERCE SITE DESIGNED FOR HOBBYISTS' METAL NEEDS



Fox Valley Metal-Tech (FVMT) introduces an online metal fabrication quoting and ordering system. At a value price, hobbyists are able to receive faster quotes with an easier ordering and tracking process for their metal parts.

The website is located at **www.fvmt.com/ebusiness.asp**. Custom metal parts can be instantly designed, quoted, and purchased online. Material cut to size can also be instantly quoted and ordered through the site. Additionally, complex fabrication projects can be submitted for fast quotes and order processing.

The FVMT e-commerce site makes it easier to do business together. "For years we have listened to the problems of our customers and are aware of the demands of fast quotes and speedy delivery," states Ed Cavil, Fox Valley Metal-Tech President. "This ordering system matches FVMT metal fabrication quality with fast and value-priced solutions and drives closer collaboration with customers, ensuring their specific needs are met on a timely basis."

Current customers have reported clear advantages of the FVMT website. With custom specifications, users are able to design their own metal part and see a drawing of the part before ordering. Customers can order their parts 24/7 with the simple ordering process. This significantly reduces cycle time for fast delivery. Moreover, the online tracking capabilities allow customers to monitor the status of their order at all times.

The FVMT website is available for online quoting and order processing of almost any hobbyist metal project.

For further information, contact:

FOX VALLEY METAL-TECH
Tim Gilbertson
1201 Parkview Rd.
Green Bay, WI 54304
Phone **1-800-469-9004,** ext. **1031**
Web: **www.fvmt.com/ebusiness.asp**

Circle #79 on the Reader Service Card.

NEW FULL LINE PRODUCT GUIDE

Global Specialties releases its new 68 page four-color Full Line Product Guide.

This new, easy-to-read Product Guide, which was introduced for the first time at EDS' 2003 show in Las Vegas, was presented to all of the Global Sales Representatives and Distributors that were in attendance.

This Product Guide reviews Global Specialties mission statement, ordering and customer service, 800 phone numbers and email addresses, and both a pictorial index and life-style header, and information section for each product category covered.

All the important functions and features of each product in the particular sections are presented, as well as a complete specification area at the end of the product category.

Many of the models offer additional specifications for the same cost or less than their competitors and all models feature Global's unsurpassed quality, service, and value commitment.

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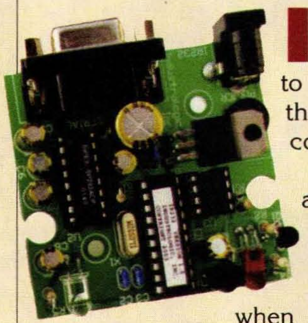
IR232 CONVERTER



Industrologic, Inc., announces the release of their IR232, an infrared to RS-232 converter that is based on the Sony SIRCS protocol of 12-bit control codes.

The IR232 can not only send and receive control codes in one of two binary modes, but can also be configured to send pre-defined character strings to the serial port when specified infrared control codes are received. This mode allows it to act as a host to any slave device that can accept RS-232 commands.

The IR232 printed circuit board assembly contains a 40 KHZ infrared receiver module, a high-power infrared LED, and a visible LED for confirmation of transmissions. It has a true RS-232 interface with DB9 connector that matches the pin out on PC compatible RS-232 ports, and can communicate at speeds up to 19200 baud.

Its onboard +5 volt power supply can operate from a wide range of input voltages provided through a pin-type power jack, and the +5 volt supply is available on pin 9 of the DB9 connector to power auxiliary devices.

The IR232 is available as a complete circuit board assembly, or can be enclosed in an optional ABS plastic enclosure with infrared window. The circuit board is 2.25 x 2.25 x 0.75 inches, while the enclosure is 2.6 x 2.6 x 1.1 inches total size.

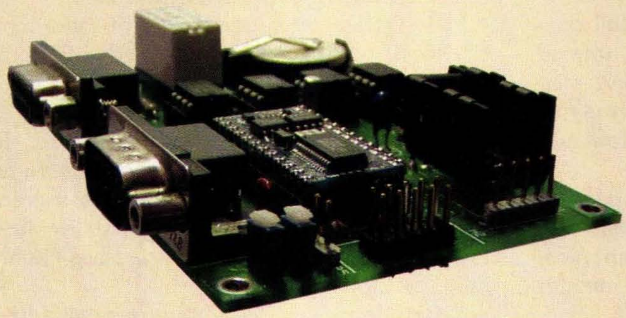
The IR232 is shipped with all items needed for immediate use: The complete circuit board assembly, a wall block power supply, an RS-232 cable for connection to PC compatible computer during setup, and terminal emulation software for the PC.

For more information, contact:

INDUSTROLOGIC, INC.
3201 Highgate
St. Charles, MO 63301
636-723-4000 1-800-435-1975
Web: **www.industrologic.com**

Circle #81 on the Reader Service Card.

NEW POWERBOARD



Logicboards releases its next generation of processor development boards, with a family of add-on daughterboards in the works, and slated for release in the Fall 2003.

The Powerboard provides core resources to a huge majority of projects developed by the users of the Parallax BASIC Stamp 2 (e,p,sx) series of microcomputers.

Centered around non-volatile devices, the Powerboard provides 128K EEPROM, date/time/day-of-week clock-calendar (with lithium battery backup), digital temperature, A/D conversion, external load switching, expansion bus, liquid crystal display, power jacks (or terminals), communication and programming ports, and onboard voltage regulation.

Logicboards has recently completed their third production of the Powerboard, making them immediately available, individually or in large volume. Provided with board layout, schematics, programming samples, and electronics, the Powerboard is a complete single board computer.

For more information, contact:

LOGICBOARDS
P.O. Box 1053
Saranac Lake, NY 12983
1-888-564-4201 Fax: **518-891-6821**
Web: **www.logicboards.com**

Circle #82 on the Reader Service Card.

Ben Clock — Part 1

Bring a little bit of London into your home with this "Big Ben Clock" with a unique LED twist.

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!

Many years ago, the LED digital watch died away. The primary reasons for this were the advantages offered by LCD displays — namely, much lower power consumption and the ability to be viewed in full daylight conditions. Unfortunately, the black and white LCD displays are rather dull looking. Well, LEDs haven't really improved in the power consumption department, but they are certainly brighter these days.

For some time now, I have noticed red LED taillights on cars. These LEDs are ultra-bright and are very easily viewed in full daylight conditions. More recently, I have noticed LED traffic lights. The traffic lights are also very bright, but they are different than the taillights, in that they come in both yellow and green colors.

This advance in LED brightness led to the development of this project. I call it Ben. It is so named after its much larger mechanical cousin, Big Ben — the famous Westminster clock.

This two-part article will discuss the design construction and operation of Ben. This month, we will discuss the theory of operation, schematics and parts list, and begin construction and testing of the PCB. Next month, we will finish up the PCB, discuss programming of the MCU, do a complete test and checkout of the electronics, and build the wooden casing.

FEATURES

Ben is a totally unique object d'art clock. Unlike its mechanical cousin, Ben's display is quite spectacular. It generates a virtual rainbow of color using 156 LEDs. Its display can be easily viewed under any lighting conditions, including full daylight. It is so bright that it made my night-light superfluous.

Ben's display is composed of three different LED colors. Thirty-six red LEDs are arranged in 12 bars of three LEDs each to indicate the hour. Next, an arc of 60 green LEDs are used to indicate the minute. The green arc "grows" larger as the time moves deeper into the hour (the minutes increase from 0 to 59). Finally, 60 single yellow LEDs are arranged in a final encompassing circle to indicate the second.

Ben generates electronic musical chimes. Specifically, the Cambridge Quarters — more commonly known as the Westminster Chime Tune song. Every 15 minutes the clock chimes a different portion of the song. It chimes the full song on the hour, and one bong for the hour number. You can tell the approximate time just by listening to the clock. A volume control is provided so you can listen in noisy environments or to tone it down to avoid being woken up.

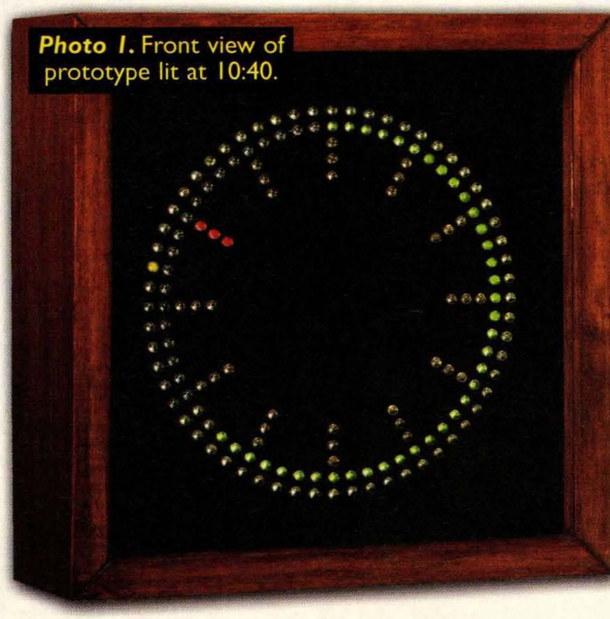


Photo 1. Front view of prototype lit at 10:40.

Ben has a long-life, self-recharging, NiMH battery backup system, which allows the clock to maintain accurate internal timekeeping for up to 12 hours during a power failure.

Ben's time-reference component is an AT cut-quartz crystal. This provides excellent accuracy, which greatly exceeds that of most mechanical timepieces.

The only moving parts in Ben are its time setting buttons, volume control, and speaker. Since there are virtually no moving parts and all components are operated well within their maximum ratings, the clock should last for a very long time before requiring any servicing.

THEORY OF OPERATION

Please refer to the schematic diagrams while reviewing this section.

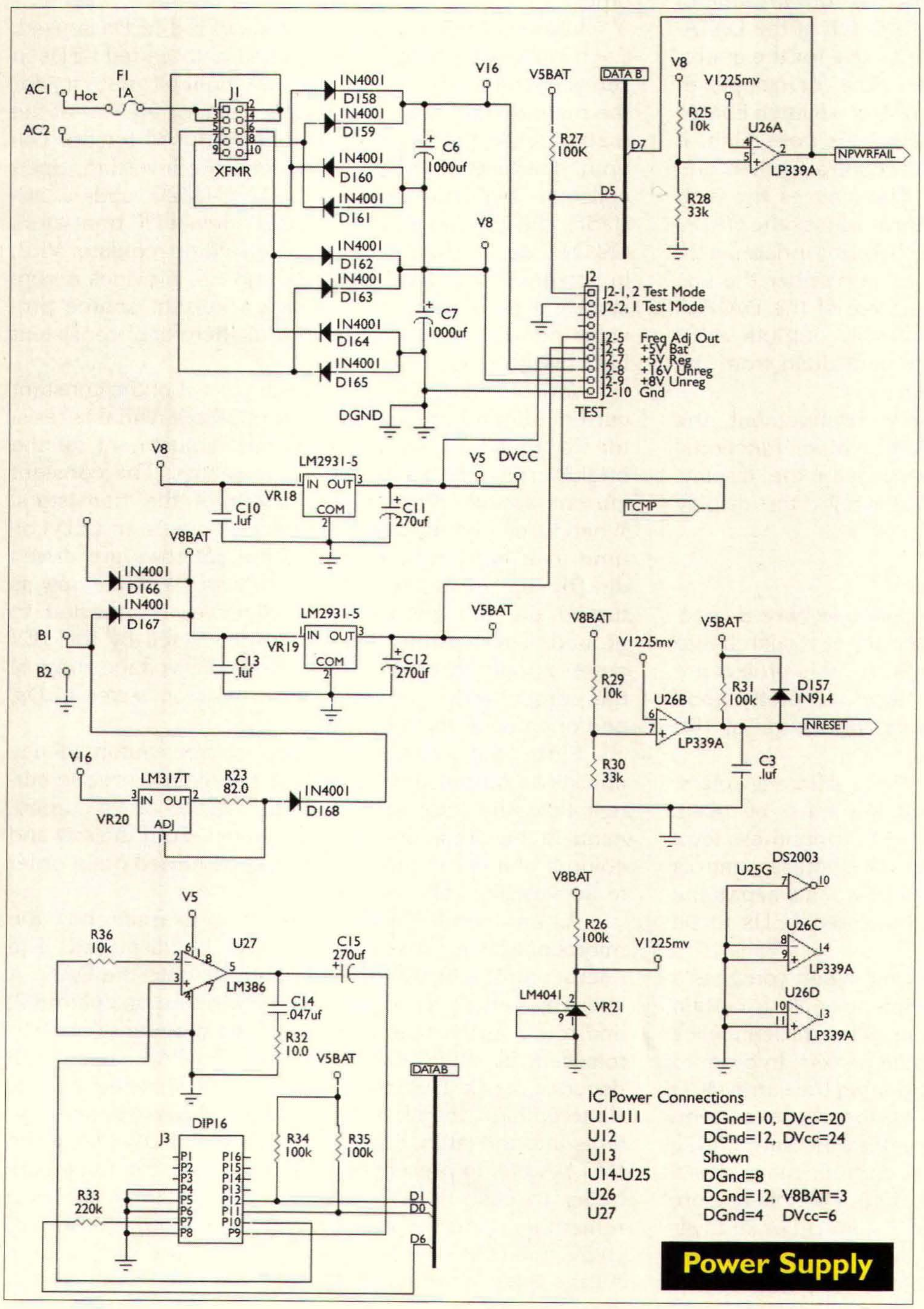
Power Supplies

Due to the relatively large current consumption of the LEDs, Ben is operated from AC wall current (115VAC). The line current passes through fuse F1 to drive the transformer XFMR1. The transformer is a split primary, split secondary type. The primary windings are operated in parallel. (It should be possible to run the primary windings in series for operation in countries using 230VAC.) The outputs from each independent secondary winding are separately rectified using two full-wave bridge rectifiers composed of diodes D158-D161 and D162-D165. The rectified supplies are filtered using capacitors C6 and C7. The filtered outputs are "stacked" to provide 8V and 16V power supplies under full load conditions. The 8V and 16V supply voltages may be much higher if the supplies are not fully loaded. (Note that the load can vary markedly, depending on how many LEDs are illuminated at any one time.)

The 8V filtered supply is used to drive a low-dropout, 5V voltage regulator — VR18. A capacitor, C10, must be used on the regulators input due to its proximity to the 8V power supply. Capacitor C11 provides additional filtering of the regulator's output. Note that capacitor C11's equivalent series resistance (ESR) must be within a specific range of about 0.1 to 0.8 ohms. Failure to select a capacitor within this ESR range will cause the regulator to oscillate. The output of the regulator provides a 5V supply used for the non-essential digital circuitry (not requiring battery backup).

The 8V power supply is mixed with the battery B1 via diodes D166 and D167 to form the 8VBAT supply. The 8VBAT supply is maintained by the battery during an AC power failure. During normal AC operation, the battery supplies no current.

The 8VBAT source is used to form a second 5V power supply — very similar to the first — called 5VBAT. The 5VBAT supply is composed of capacitors C12, C13, and voltage regulator VR19. As with the first 5V supply, capacitor C12 must be chosen within the same specific ESR range. The 5VBAT supply is used to power critical circuitry, which must have power maintained during an AC power failure — namely, the microcontroller.



Power Supply

Battery System

The battery backup unit B1 consists of a nickel metal-hydride battery. This type of battery has a distinct advantage over a NiCD type in that it has no "memory." That is, it can be discharged and recharged continually without affecting its performance.

A battery trickle charger is employed to keep the battery charged during normal AC operation. The trickle charger uses voltage regulator VR20 in a constant current arrangement. Resistor R23 "programs" the regulator to deliver approximately 15mA. Diode D168 provides protection in case the battery is inserted backwards. Once the battery is fully charged, excess current being delivered by the trickle charger is bled-off into the 8VBAT power supply.

Display Memory

The microcontroller has a limited number of output lines, so an external memory circuit is used to remember the state of the display. This memory circuit is composed of octal latches U1-U11 and a four to 16 line demultiplexer U12.

When the microcontroller wants to "program" one of the latches, it sets up the data for the latch of the DATA-A bus. It then outputs the latch select code for the appropriate latch on the DATA-C bus. The demultiplexer expands the latch select code into one of 16 latch enable lines. When one of the latch enable lines goes high, it enables a particular latch. The microcontroller then outputs a "0" onto the DATA-C bus. This causes the high latch enable line to go low. This, in turn, causes the DATA-A bus contents to be clocked into the appropriate latch. The programmed latch continues to remember the last data clocked into it, even after the state of the DATA-A bus changes. The microcontroller finally outputs a "0" onto the DATA-A bus to prevent current drain from the microcontroller during a power failure.

By using this external memory arrangement, the microcontroller is left free to attend to other functional needs without having to continually scan the display. Also, since the LEDs are driven statically, the display brightness is markedly increased.

LEDs

One of my goals for this project was to have a spectacular display. So, I did a large amount of research into LED specifications. The LEDs I chose for this project are the Fairchild HLMP-3X50 series. I have had pretty good luck with brightness matching buying bulk bags of 100 LEDs in each color from Digi-Key.

Since the clock uses LEDs of three different colors, LEDs from different manufacturing lots must be used. The green LEDs are fixed at a particular brightness level by being driven at precisely 20mA. Brightness controls are provided for the red and yellow LEDs. This allows the brightness level of all the different colored LEDs to be made equal.

LEDs are current-operated devices. When you pass a particular current through the device, it emits a certain brightness. The brightness is rated in millicandellas (MCDs are about 1/1,000 of a candle power). In order to guarantee that the LEDs are all generating the same MCD level, the LEDs must be driven at the same current. Unfortunately, any two LEDs generating the same MCD level and being driven by the same current may have a markedly different forward voltage drop. For this reason, I had to abandon the idea of using a conventional driver circuit such as a series resistor. Instead, the circuit uses voltage regulators operated in a constant current mode configuration to drive the display.

In order to achieve the maximum possible brightness from the display, I also abandoned the idea of "scanning" the display. This would have greatly reduced the component count for the project, but would have also severely impacted the display brightness. Instead, the circuit uses octal latches to provide static drive to the display. The MCU "tells" the display driver circuit which LEDs it wants lit.

Display Drivers

For the hour and second displays, matrices are used since only one cell of each matrix needs to be active at a time.

In the hour case, a 3 x 4 matrix of red LEDs is used. Each cell of the matrix is composed of three red LEDs in series. Octal latch U3 serves as an eight-bit memory for the matrix. The lower four bits are used for the row of the matrix, while the upper three bits are used for the column. The outputs of the latch feed the inverting, open collector, high-current drivers, U22E-U22G and U25C-U25F. The column elements further drive PNP transistors Q9-Q11 via resistor pack R21. The voltage regulator VR2, in conjunction with resistors R2 and R4, provides a constant current source. The constant current source provides consistent current flow and, therefore, consistent LED brightness.

Variable resistor R4 allows adjustment of the constant current output from about 10mA to 30mA. Variable resistor R4, therefore, acts as a manual adjustment for the brightness of the entire red hours matrix. The constant current source drives the emitters of the transistors. When turned on, a transistor collector drives an LED column to a high voltage level. The LED rows are driven directly by the open collector drivers. When a row is turned on, the entire row is effectively connected to ground. The constant current source is fed by the 16V power supply in order to overcome the voltage drop of the components — namely, the transistor, series LEDs, and open collector driver.

Since the constant current source automatically adjusts its output voltage level to maintain a precise current flow, the total voltage drops for the other components in the circuit are inconsequential. Both the row and column of a cell in the matrix must be turned on in order to activate the cell.

As an operational example, let us examine how the microcontroller causes hour five to be displayed. The microcontroller first outputs 00100001 onto the DATA-A bus. This sets up the data necessary to turn on column 2, and row 1 of the hour matrix. It then outputs 00001011 followed by 00000000 onto the DATA-C bus. U12 decodes the DATA-C bus causing the latch select line for U3 to go high, then low. This clocks the DATA-A bus contents into the latch. Finally, 00000000 is output onto the DATA-A bus to prevent current drain from the microcontroller in case of an AC power failure. Latch U3 now remembers and outputs 00100001. Since the inputs of U25C and U22F are high, their outputs turn on (go low). All the other open collector driver outputs connected to

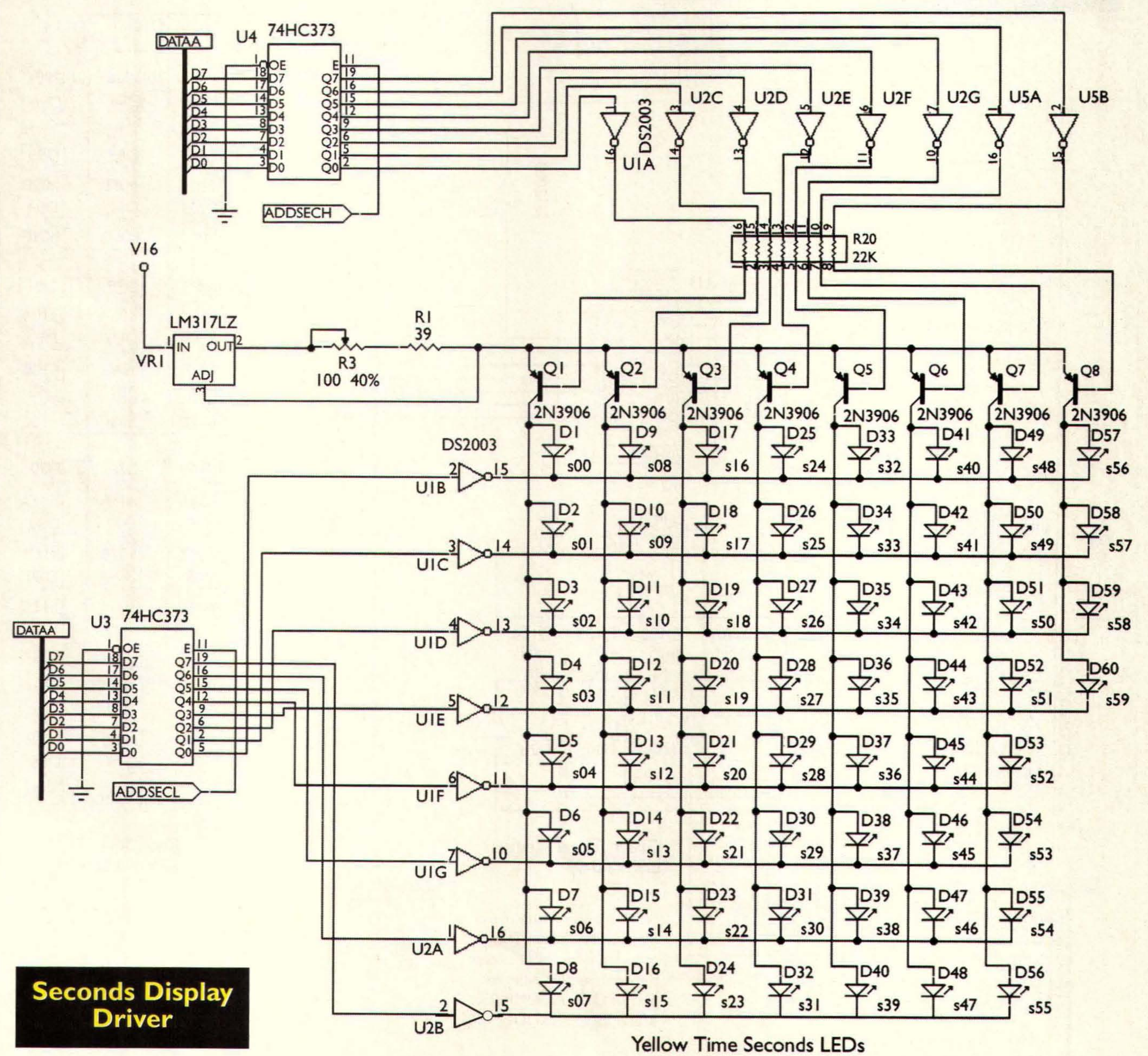
U3 are in a high-impedance state. U22F drives Q10 into conduction. Current then flows from the constant current source VR2, through Q10, into LEDs D82-D84, and finally through U25C to ground. Only LEDs D82-D84 (hour 5) are illuminated. All the other LEDs in the matrix are extinguished since both their row and column drivers are not turned on.

The seconds matrix is very similar except that it is a bit larger. In the seconds case, an 8 x 8 matrix is used. All eight bits of octal latch U1 are used for the row memory, while all eight bits of latch U2 are used for the column memory. The open collect drivers, transistors, and constant current sources provide power to the LEDs just as in the hours matrix. Variable resistor R3 provides a manual brightness control for the entire yellow seconds matrix.

The green minutes LEDs are driven utilizing a somewhat different method. In the hours and seconds cases, only one cell of each matrix needs to be active at any one time. Since the green LEDs form a growing arc of light, it is necessary to have between one and 60 LEDs lit at a time. For this reason, a matrix cannot be employed. Instead, eight driver circuits are used.

Each of the driver circuits controls up to eight green LEDs. Octal latches U4-U11 operate as eight, eight-bit memory cells. High-current, open collector drivers U14A-U22D directly drive the LEDs. Regulators VR3-VR17 act as 15 independent constant current sources. Since all the eight driver circuits are virtually identical, we will examine only one in detail; namely, the driver for minutes 00-07.

The green minute 00-07 driver circuit is composed of octal latch U4, inverting open collector drivers U14A-U15A, and two constant current sources VR3 and VR4.



Seconds Display Driver

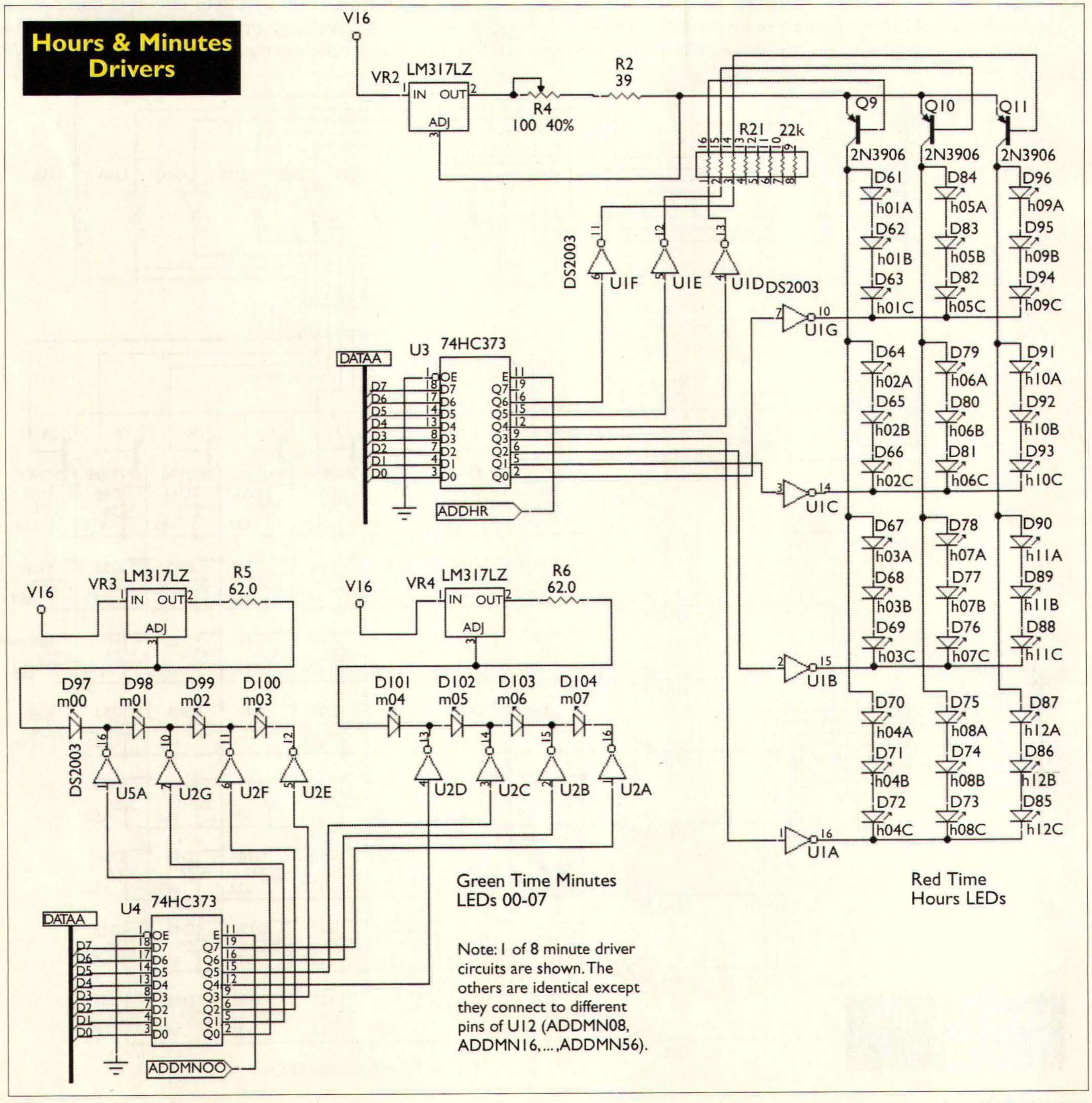
Each constant current source drives four LEDs. The reason only four LEDs are driven is because of the maximum voltage drop of the components. The driver circuit uses a single bit of the latch to control the state of each LED.

If, for example, the microcontroller outputs 00000001 into latch U4, only U14A will turn on (go low). In this case, current flows from the constant current source, through LED D97 (minute 00), and finally through inverting driver U14A to ground. This causes minute 00 to be illuminated. All other LEDs controlled by U4 are extinguished since all the other open collector drivers are in a high-impedance state. The microcontroller, by programming the successive values 00000001, 00000010, 00000100, 00001000 into the latch, cause one, two, three, and finally four LEDs in the chain to be illuminated. By outputting similar values to the other latches, the chain can be further illuminated up to 60 green LEDs.

The other minutes' driver circuits are identical except that their octal latches are connected to different output pins from the demultiplexer U12. This allows each of the octal latches to be independently addressed.

Power-failure/Low-battery Detection

A voltage reference composed of R26 and VR21 provides a 1.225V reference voltage for the comparator U26



to make measurements against.

To detect an AC power failure, voltage dividers composed of resistors R25 and R28 divide down the 8V power supply. U26A compares the output of the voltage divider to the reference voltage. When the 8V supply falls too low, the output of the divider becomes less than the 1.225V reference voltage. This causes U26A's output to go low. The comparator output causes an interrupt condition on the microcontroller via the DATA-B buses D7 line. (The microcontroller provides an internal pull-up resistor on input lines used for interrupt conditions.) Upon interruption, the microcontroller immediately ceases further communication with the peripheral circuitry. This stops the peripheral circuitry from being damaged or draining power from the microcontroller output pins. This also extends the battery life.

U26B, along with resistors R29 and R30, are used to detect a low battery condition. When a low battery condition is detected, the microcontroller is forced into a reset state. This prevents the microcontroller from "going crazy" due to a lack of proper power. Components R31, C3, and D157 allow the power supplies to stabilize after the AC power is restored before releasing the microcontroller from the reset state.

Music/Tone Generation

The microcontroller uses the DATA-B buses D6 line to generate audio signals. The audio signals are simply square waves of the appropriate frequency for the desired musical note. The square wave voltage level is divided down via R33, and the volume control pot. The divided output is then used to directly drive audio amplifier U27. The output of the audio amplifier chip drives the speaker.

Microcontroller

At the heart of Ben is a Motorola CMOS microcontroller unit U13. The microcontroller (MCU) used is the 68HC05C8ACP. This is an eight-bit MCU with 8K of One Time Programmable (OTP) ROM — 352 bytes of RAM, built-in timer, and 32 I/O lines. The MCU is capable of being run at speeds of up to four MHz.

This MCU is a great choice for several reasons. First, it's reasonably priced. It's CMOS technology, so the power consumption is fairly low, which is an important consideration for the battery backup unit. It also has a large number of I/O lines, which are used to drive the display circuitry, detect button presses, etc. Finally, using an MCU allowed me to program some interesting features into Ben. These include auto-repeating and time-set buttons, which operate similar to a PC keyboard. Musical tone generation is accomplished by toggling one of the MCU output lines to generate square waves of different frequencies and durations all under MCU program control.

The MCU uses an AT cut crystal as a time base. I used a ±1 ppm tolerance part. Note that the one ppm tolerance is really the tolerance of the crystal over its full operating temperature range of 0 to 70° C. Crystals drift mainly due to operating temperature variation. Since the clock will presumably be in a somewhat climate-controlled room, the actual accuracy of the clock is much better than one ppm. This level of accuracy is superior to most digital watches, and greatly exceeds that of most mechanical timepieces. In order to facilitate an accurate adjustment of the timekeeping function, you may use variable capacitors C4 and C5 in place of the fixed value capacitors C1 and C2. A test mode (described later in the construction section) allows precise adjustment of the crystal oscillator if you use the variable capacitors.

Since we're focusing on electronics rather than software, I will not go into a deep discussion of the microcontroller's firmware operation. Suffice it to say that the firmware exercises the peripheral circuitry as previously discussed.

You can obtain a free manual from Motorola for the microcontroller or view it online. The manual describes all the microcontroller technical features. It also contains a schematic for a programming board, which will allow you to "burn" the firmware into the microcontroller. The Motorola website is located at **http://e-www.motorola.com/webapp/sps/library/docu_lib.jsp**. If you are looking for online documentation, do a search for "Product or Technology: Microcontrollers," "Family or Function: 8-Bit," "Sub-Family or Sub-Function: M68HC05," "Product: 68HC05C8A." To see the technical data, locate MC68HC705C8A/D in the data sheet section of the returned results. You can also order the free printed version of the manual from here.

Motorola also manufactures a development system for this microcontroller. It gives you the ability to do non-realtime emulation, in-circuit emulation, out-of-circuit simulation, and EPROM/OTP programming. The development system is called the M68ICS05C. You can get more information by visiting the hyperlink given above and selecting "Tools." Use the same search parameters. The website will give you a list of distributors carrying the ICS.

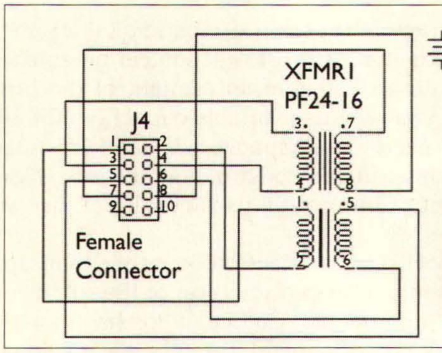
Note: The kits containing the MCU come with a preprogrammed MC68HC05C8ACP, so if you buy one of the kits, there is no need to worry about programming the microcontroller yourself.

If you want to program your own microcontroller, I have provided a Motorola s-record format machine code listing later in this article.

CONSTRUCTION

Transformer Wiring Harness

The transformer is mounted off the main PCB on the bottom of the wooden frame. The reason this is done is to provide the correct center of gravity for the unit to keep it from tipping over. A simple wiring harness must be constructed for the transformer. The transformer is connected to the PCB via connector set J4/J1. If you use the recommended transformer in the parts list, please note that the pins on the transformer do not run in order (so pay careful attention when wiring the transformer). Also, please note that J4's pins run left to right and top to bottom (unlike an IC which runs top-left to bottom-left and bottom-right to top-right). You should make the wires about 12 inches long. Crimp or solder pins for the connector to one end of the wires and insert the crimp pins into connector



Transformer and Wiring Harness

J4. Cut off the PCB mounting pins on the transformer with a wire cutter. Then solder the ends of the wires to the appropriate pins of the transformer. The connector's pin numbers correspond with the transformer's pin numbers. That is, pin one of the connector goes to pin one of the transformer, and so forth.

Printed Circuit Board

In order to simplify construction, I designed a PCB. The PCB is of the two-sided variety. If you attempt to home brew the PCB, please note that the board employs a large number of vias (feed-throughs). If you make your board without plated through-holes, you will need to solder components on both sides of the board and solder in wires on both sides for each via. Since the board is somewhat complex, I highly recommend you use the board available with the kits. If you use the plated-through PCB offered with the kits, you will need to solder the component leads on one side of the board only.

The PCB has components mounted on both sides.

Schem Ref	Manufacturer	Part Number	Description	Distributor/Part Number
B1			Battery, 9V, NiMH	
C11-C12, C15	Panasonic	EEU-FC1C271	Capacitor, 270uF, 16V, electrolytic, radial	Digi-Key P11200-ND
C14			Capacitor, 0.047uF, 50V, Ceramic, radial	
C1-C2			Capacitor, 27pF, 200V, 5%, ceramic, radial	
C3, C8-C10, C13			Capacitor, 0.1uF, 50V, ceramic, radial	
C6-C7			Capacitor, 1000uF, 35V, electrolytic, radial	
D157			Diode, 1N914, 200mA, DO-35	
D158-D161			Diode, 1N4001, 1A, 50PIV, DO-41	
D1-D60	Fairchild Semiconductor	HLMP-3950A	LED, HLMP-3950A, Ultrabright Yellow, T1-3/4 with standoff	Digi-Key HLMP3850AFS-ND
D61-D96	Fairchild Semiconductor	HLMP-3750A	LED, HLMP-3750A, Ultrabright Red, T1-3/4 with standoff	Digi-Key HLMP3750AFS-ND
D97-D156	Fairchild Semiconductor	HLMP-3950A	LED, HLMP-3950A, Ultrabright Green, T1-3/4 with standoff	Digi-Key HLMP3950AFS-ND
F1			Fuse, 1A, pigtail leads	
Q1-Q11			Transistor, 2N3906 PNP General-Purpose Amplifier and Switch, TO-92	
R1-R2			Resistor 39 Ohm, 1/4W, 5%	
R22			Resistor, 10M Ohm, 1/4W, 5%	
R23			Resistor, 82 Ohm, 1/4W, 5%	
R24, R26-R27, R31, R34-R35			Resistor, 100K Ohm, 1/4W, 5%	
R25,R29, R36			Resistor, 10K Ohm, 1/4W, 5%	
R28,R30			Resistor, 33K Ohm, 1/4W, 5%	
R3,R4			Trimpot, 100 Ohm, top adj, carbon, PCB mount	
R32			Resistor, 10 Ohm, 1/4W, 5%	
R33			Resistor, 220K Ohm, 1/4W, 5%	
R37			Potentiometer, 10K Ohm, Audio taper, Shaft	
R5-R19			Resistor 62 Ohm, 1/4W, 5%	
S1-S2			Push Button, Normally Open, Momentary soldertail	
Socket for U13			IC Socket, DIP-40, PCB soldertail	
SPKR			Speaker, 8 Ohm, 5W, round with square mounts	
U12			Demultiplexer, 4514, CMOS 4 to 16 line DIP-24	
U13			Microcontroller, 68HC05C8ACP, DIP-40 OTP plastic	
U14-U25			Darlington Array, DS2003CN, High current/voltage driver, open collector, DIP-16	
U1-U11			Latch, 74HC373, Octal transparent D-type with tristate outputs, DIP-20	
U26			Comparator, LP339N, Quad, Ultra low power, DIP14	
U27			Audio Amp, LM386N-1, low power, DIP-8	
VR18-VR19			Regulator, LM2931AT-5, 5V, fixed, 100mA, TO220-3	
VR1-VR17			Regulator, LM317LZ, Adjustable, TO-92	
VR20			Regulator, LM317T, Adjustable, TO-220	
VR21			Voltage Reference, LM4041, Precision ±2%, TO-92	
XFMR	Tamura	PF24-16	Transformer, 16V, 24VA, 1.5A, low profile	Digi-Key MT1112-ND
XTAL1			Crystal, 4 MHz, 1 ppm, AT cut, HC49	

Parts List Ben Clock

Note — Schematics and other files relating to building this project can be downloaded from the *Nuts & Volts* web site.
www.nutsvolts.com

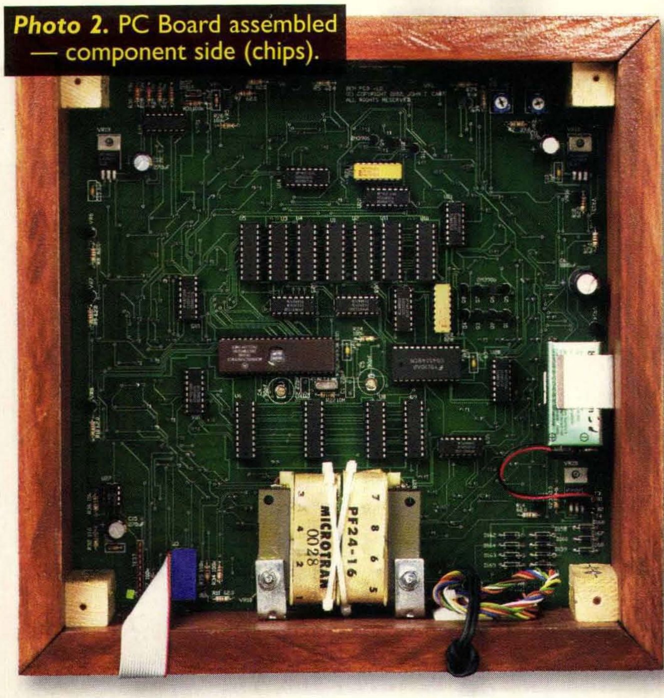


Photo 2. PC Board assembled — component side (chips).

The LEDs alone are mounted on one side and all the other components are mounted on the other side.

When constructing the PCB, I recommend placing only the power supply components on the board at first. You can then measure the power supply voltages with a DVM to make sure the voltage levels are correct before proceeding. This will prevent destroying all the digital circuitry in the unlikely event the power supply is malfunctioning. The power supply components consist of C6-C7, C10-C13, D158-D167, F1, J1, J2, VR18-VR19, and the line cord. You should solder in all these components and then connect the transformer's wiring harness connector to J1.

Please note that dangerous voltages are present on the PCB. Specifically, the power cord, fuse, and transformer connector should be avoided. You may wish to cover these components (and the associated PCB pads) with electrical tape before you plug in the unit. The same goes for the pins of the transformer itself.

Next plug in the line cord. Test connector J2 provides a means to easily measure the power supply voltages. Note that the 8V and 16V supplies may be much larger (by a factor of two or more) under a no-load condition. This is completely normal. The critical voltages to check are the 5V and 5VBAT levels, which should be very close to five volts.

After checking the power supply, unplug the line cord and disconnect the transformer connector.

NEXT MONTH

Please see next month's issue for all remaining details of the project! **NV**

by Bill Sheets and Rudolf Graf

A Simple Flea Power VHF TV Transmitter

Lose the wires with this handy device!

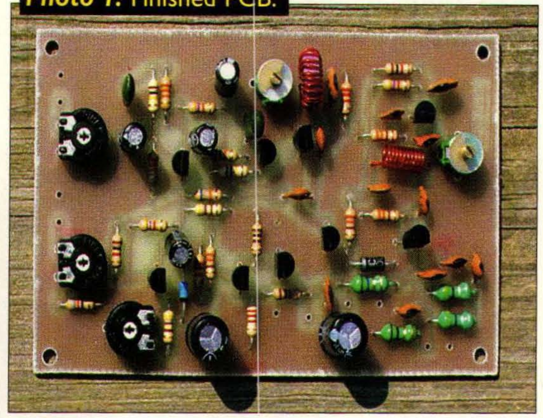


Photo 1. Finished PCB.

Have you ever had to hook up something to your TV set only to be frustrated by the inconvenience or lack of suitable connections? Also, to do this without unscrambling a rat's nest of wires, or moving heavy items to gain access to the back of the set?

If you have, this little TV transmitter will prove handy for interfacing that camcorder, video camera, game, or other device to your TV set without going through all that grief. Absolutely no connections are needed, as this device may be set to transmit anywhere between VHF CH 2 and 6 (54 to 88 MHz) and will broadcast a good quality picture and sound through a nearby TV receiver tuned to an unused channel.

The transmitter is small (PC board 2.5 x 4 inches), and can run off six AA cells, a nine-volt transistor radio battery, or any other convenient nine-volt supply with good regulation. Current drain is 45 to 50 milliamps. The transmitter interfaces with standard video and audio levels – one volt p-p neg synch NTSC or PAL video and line level audio (0.1 to 1.0 volts RMS high impedance). These video output and audio output levels are supplied by most consumer equipment having video and audio line output jacks.

The transmitter consists of a free running oscillator tuned to the video subcarrier frequency of the desired channel, which is 55.25, 61.25, 67.25, 77.25, or 83.25 MHz for channels 2, 3, 4, 5, and 6, respectively. Tuning is not too critical and a trimmer capacitor on the PC board is used to set these frequencies. The oscillator is fed to a modulated RF stage where it is modulated by the composite video and audio subcarrier. The output of this stage feeds a harmonic filter and a short whip antenna. Sufficient signal is obtained to be received on a TV set within about 30 to 50 feet of the transmitter with reasonable quality.

The video input is amplified, and DC level clamped to drive the modulator stage. Audio input is amplified, pre-emphasized, and fed to a 4.5 MHz (NTSC) or 5.5 to 6.0 MHz (PAL) VCO stage, and this VCO produces the FM audio subcarrier. This audio subcarrier is fed to the video amplifier where it is mixed with the composite video signal, and is about 5 to 10 percent of the peak video amplitude. A block diagram of the transmitter and the schematic is shown in Figures 1 and 2, respectively.

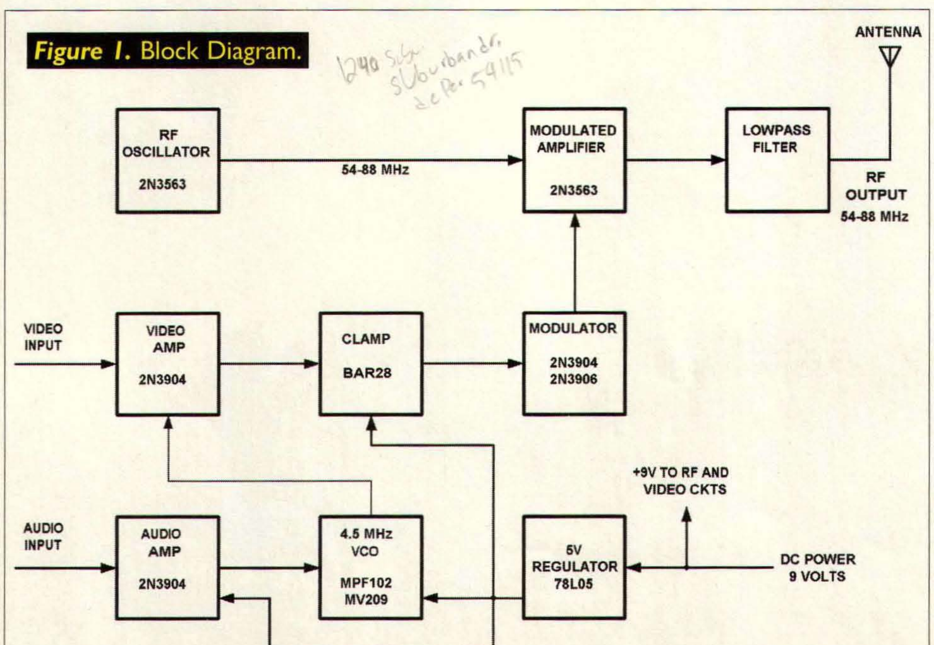


Figure 1. Block Diagram.

Referring to Figure 2, a circuit description follows. Q1 is an RF oscillator and is used to generate the picture carrier signal. R1, R2, and R3 bias Q1, C1, and C2 are bypass capacitors. The frequency is determined by the inductance of L1 and the total circuit capacitance, made up of frequency setting trimmer C4, feedback network C3 and C5, and C4 in series with the input capacitance of amplifier stage Q2.

C4 has sufficient variation to allow the frequency to be set between 54 and 88 MHz. R5 provides bias for modulated amplifier Q2, whose collector supply voltage is derived from the video modulator circuitry. The collector of Q2 feeds an output network and low pass filter to suppress harmonics of the video carrier frequency. This consists of coupling capacitor C7, and filter components L3, L4, C9, C10, C11, and DC grounding choke L5. A short (12 inch) whip antenna is coupled to output jack J3. Do not make this whip any longer than needed. You do not want to broadcast a signal beyond your property boundaries or cause interference to other TV sets.

Video input is fed to video amplifier stage Q3 and associated components, gain control R7, terminating resistor R8, bias and gain setting resistors R9 and R10, and collector bias resistor R12. This stage has a gain of about 0 to 4X, depending on the setting of R7. The amplified and inverted (sync positive) video appears across R15 and clamp diode D3. C14 is a large bypass capacitor, because it must function as a bypass down to 10 Hz, and provide a steady DC level at the junction of R13, R14, and R15, of about 3.5 to 4.5 volts. C13 is a video coupling capacitor and D3 clamps positive sync pulses to this nominal four-volt level, setting the DC level on the base of Q4. Q4 is DC-coupled to modulator transistor Q5, which feeds a combined DC bias and high-level video signal to RF amplifier Q2. R16 and R17 set the gain of this stage.

R27 is a variable potentiometer to adjust the DC clamping level of Q4 so that the modulator provides full output on sync tips without saturating and clipping them off. This would cause video sync instability on the received picture. The output of the modulator at the collector of Q5 swings between two and eight volts, with a nine-volt power supply voltage. This voltage is fed to the collector of Q2 through RF choke L2. C8 is an RF bypass for VHF, but has little effect on video frequencies (DC to 4.5 MHz).

Skills needed for this project are the ability to solder, assemble a PC board, component identification, read color codes on resistors, and most of all, to be careful to read and follow directions. A basic VOM and a small nine- to 12-volt power supply or battery will be needed to test-run this device. A source of video and audio (a VCR or DVD player, or a video camera will do), and a TV set to monitor the picture should be available. Some electronics experience (not computer or audio experience, these teach very little about actual electronics theory and construction) such as radio-TV-VCR servicing, bench circuit troubleshooting and repair, using test equipment, robotics, having built other electronics projects, or ham radio experience is best.

Audio transmission is via a subcarrier at 4.5 MHz (NTSC) or 5.5 or 6.0 MHz (PAL). FET Q7 is a colpitts VCO

Photos 2A & 2B. Finished Transmitter.

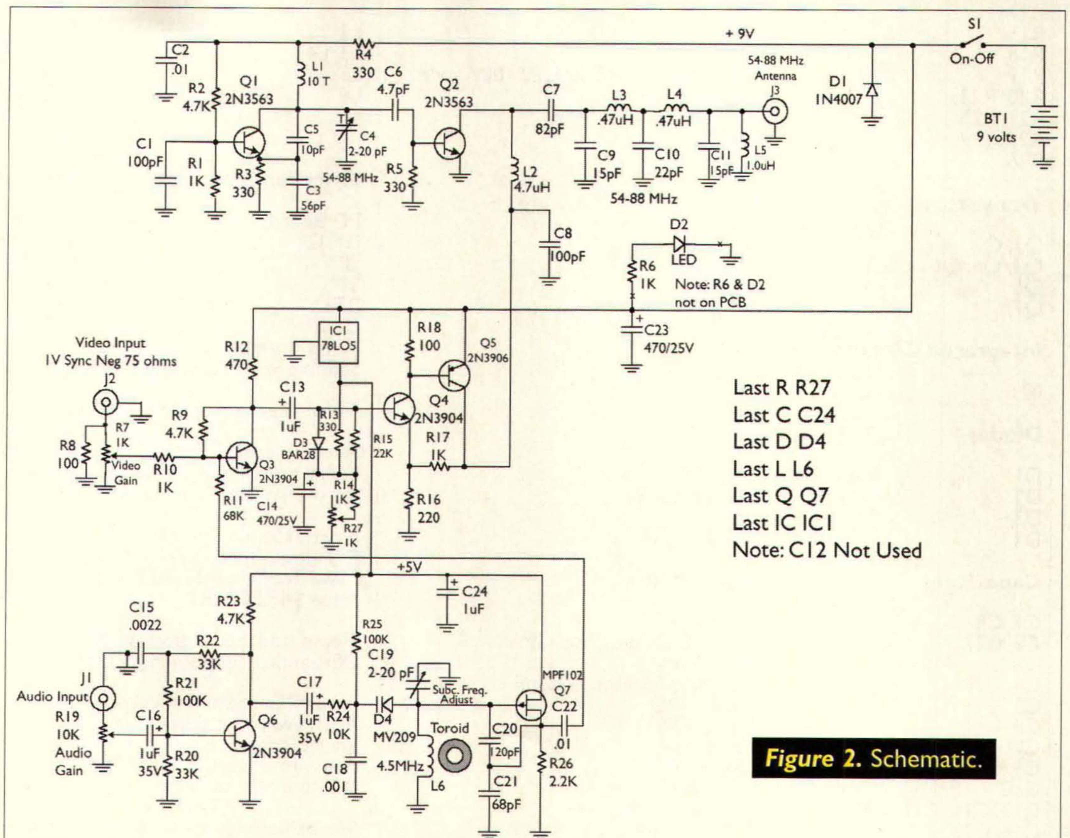


Figure 2. Schematic.

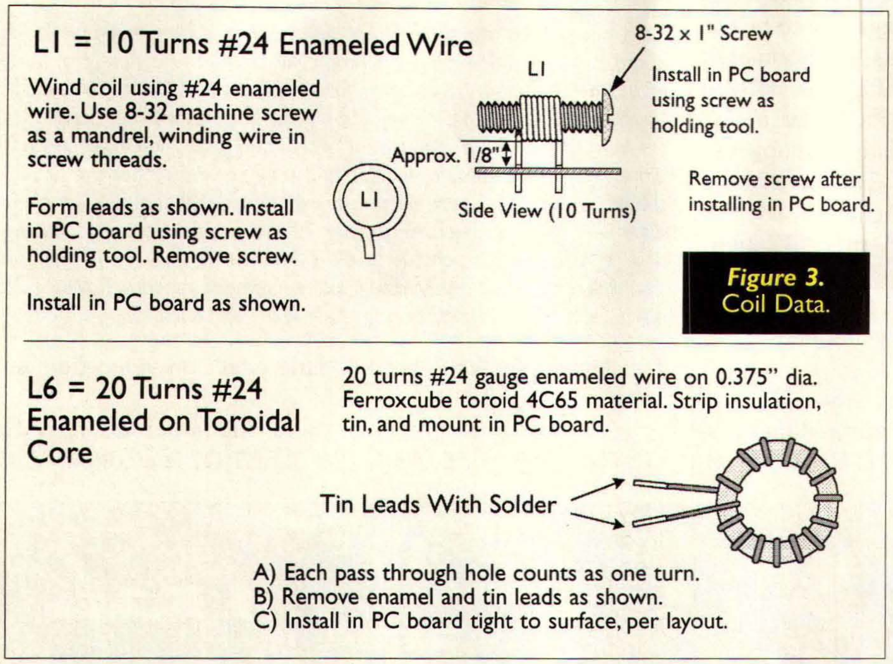


Figure 3. Coil Data.

operating at the sound subcarrier frequency. The frequency is determined by the circuit capacitance across toroidal inductor L6. This is made up of the capacitance of varactor diode D4, trimmer C19, and the feedback network C20 and C21. Q7 is biased by source resistor R26 and has its gate DC grounded via L6. C24 AC grounds the drain circuit of Q6. With correct adjustment of C19, the nominal frequency is set to 4.5 MHz for NTSC and 5.5 or 6.0 MHz for PAL. The subcarrier is fed into the video amplifier via capacitor C22 and resistor R11.

Audio input at J1 is fed through gain control R19 and coupling capacitor C16 to the base of audio amplifier Q6, R20, R21, R22, and R23 bias Q6. C15 is a bypass capacitor. Audio from the collector of Q6 is coupled via C17 and R24

PARTS LIST

Resistors 1/4W 5%	Value
R1,R6, R10, R14, R17	1 KΩ
R2, R9, R23	4.7 KΩ
R3, R4, R5, R13	330Ω
R7, R27	Potentiometer, 1KΩ, PT10LV style
R8, R18	100 Ω
R11	68 KΩ
R12	470 Ω
R15	22 KΩ
R16	220 Ω
R19	Potentiometer, 10 KΩ, PT10LV style
R20, R22	33 KΩ
R21, R25	100 KΩ
R24	10 KΩ
R26	2.2 KΩ

Transistors	P/N
Q1, Q2	2N3563
Q3, Q4, Q6	2N3904
Q5	2N3906
Q7	MPF102

Integrated Circuits	P/N
IC1	78L05

Diodes	P/N
D1	1N4007
D2	LED, any color
D3	BAR28
D4	MV209

Capacitors	Type & Value
C1, C8	100 pF NPO
C2, C22	.01 uF Ceramic Disc, GMV
C3	56 pF NPO
C4, C19	Trimmer, 7.5 mm. 2-20 pF
C5	10 pF NPO
C6	4.7 pF NPO
C7	82 pF NPO
C9, C11	15 pF NPO
C10	22 pF NPO
C13, C16, C17, C24	1 µF / 35V elec
C14, C23	470 µF / 16V elec
C15	.0022 µF 50V mylar
C18	.001 µF 50V mylar
C20	120 pF NPO
C21	68 pF NPO

Coils and Chokes	Value and Type
L1	10 T # 24 enamelled, 8-32 screw thread
L2	4.7 µHy RF Choke
L3, L4	0.47 µHy RF Choke
L5	1.0 µHy RF Choke
L6	Toroid, 20T #24 enamelled wire on 4C65 Matl 3/8 dia toroid core (Fxcube)

Miscellaneous Parts	Value or Type
PC Board	P/N 031703B
J1*, J2*	RCA Jack, 1/4 inch dia, panel mount
J3*	BNC Connector, panel mount
S1*	SPST Toggle switch
BT1*	Battery Assembly 9V
Case*	NC531 Metal (Preferred) or Plastic
Whip Antenna *	12 inch nominal with BNC fitting

Suitable wire, solder, and hardware as needed*

* Not on circuit board and not included in kit

A complete kit consisting of an etched, drilled, and screened PC board and all the parts that mount on it to make a complete working transmitter is available from:

North Country Radio
P.O. Box 53, Wykagyl Station
New Rochelle, NY 10804-0053
Price $49.50 USD

Please add $6.00 postage and handling to all USA addresses. Non-USA addresses should include $10.50 USD for postage and handling.

A suitable painted two-toned metal case is available for $13.50 USD. A hardware kit consisting of all hardware, spacers, jacks, and cable is available for $ 10.50. A collapsible whip antenna with BNC fitting for use with this kit is available for $14.50. NY state residents please add 8.25 percent sales tax.

For other kits, please visit **www.northcountryradio.com** to the varactor diode D4. C18 acts as an RF bypass cap and has little effect on the audio. D4 is biased to a regulated five volts via R25. The audio is superimposed on this bias voltage causing the capacitance of D4 to vary with the audio signal. This results in frequency modulation of the VCO circuit; ±25 kHz deviation is needed for 100 percent modulation, and this circuit easily accomplishes this with good audio fidelity.

IC1 provides regulated five volts for the audio, varactor, and DC video clamp reference bias circuit. This keeps the video and audio circuitry operating properly as the input voltage varies with normal battery aging. At least 7.5 volts is needed for proper functioning. This circuit can be operated on supplies up to 12 volts with no ill effects, but it was designed for a nine-volt supply. With higher voltage supplies, more RF output is produced, so keep the antenna short. D1 acts as a polarity protection device and will limit reverse voltage to 0.6 volts. C23 is the supply bypass. R6 and LED D2 act as an optional power-on indicator light. R6 and D2 are not mounted on the PC board as they are optional. They can safely be omitted for battery operation, so as to minimize battery drain. The entire circuit fits on a 2.5 x 4 inch PC board. A full-size pattern is available for download on the *Nuts & Volts* website at **www.nutsvolts.com**.

As this is a VHF circuit, the layout should be carefully followed and the specified parts should be used in order to avoid possible circuit problems. Leads must be kept short. "Ugly Bug" construction (parts mounted on unetched G-10 copper foil PC board) was used for the breadboard, but better operation was obtained when the PC layout was used. L1 is a toroid 3/8 diameter and consists of 20 turns of #24 enamelled wire on the core specified in the Parts List.

Other cores may be used, but you are on your own as to the correct number of turns needed. L1 consists of 10 turns of #22 enamelled wire wound on an 8-32 screw thread as a former. Remove the screw thread before installing the coil, as it will cause severe detuning of the circuit and kill the oscillator. The turn spacing of L1 can be adjusted with a knife blade to get the exact tuning range needed (54-88 MHz). See Figure 3 for coil details.

After construction and making sure all component values and orientations are correct, apply +9.0 volts DC power to the board. The circuit will draw around 45 to 55 milliamperes when properly set up. Check for 5V across C24, and set R14 for 3.9 volts at the junction of R13, R14, R15, D3, and C14. Set R7 to halfway open. Apply a one volt p-p video signal to the video input J2.

While watching a nearby TV receiver tuned to an unused channel between VHF 2 and 6, very slowly adjust oscillator trimmer C4 for best picture. It may roll and tear. Adjust R27 for best stability, then R7 for best video. Repeat this procedure several times as they all interact. Ignore the audio for now. When you have a satisfactory image, apply program line level audio to J2 and listen to the audio in the TV receiver.

Set the TV receiver audio gain in the same position as

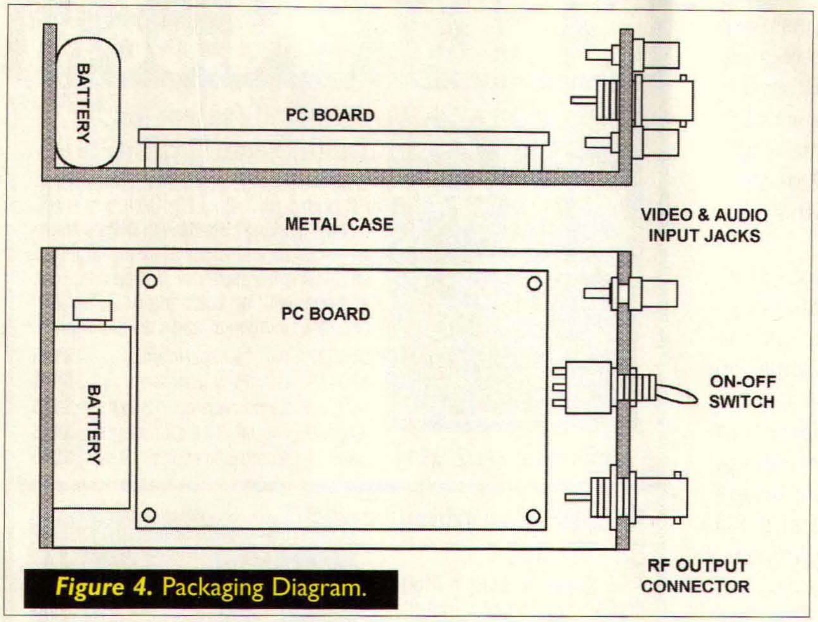


Figure 4. Packaging Diagram.

you would use for on-the-air reception of commercial programs. Slowly adjust C19 until you hear some audio. Adjust gain control R19 for best results, then go back to C19 and repeat. These two adjustments may interact. Ignore any residual buzz for now, as it will be adjusted out later. When the audio is okay, adjust clamp control R27 and video gain R7 to minimize audio buzz while maintaining good video.

Also, make sure that C4 is set for the best picture you can get. If there are colored sound bars or beats in the picture, R11 may need to be increased in value. Also, make sure sound trimmer C19 is set correctly.

The finished PC board may be used as-is or mounted in a metal (preferred) or plastic case, with a self-contained battery, with a suitable on-off switch, input jacks (RCA are recommended), and RF output connector (BNC recommended). We used an ordinary LR6 nine-volt transistor battery (alkaline), but much better life will result if six AA cells are used in a series arrangement to supply nine volts. Nicads can be used, but seven (8.4V) or preferably eight (9.6V) cells should be used.

Do not use the nicad nine-volt rechargeable transistor radio batteries, as they are only rated for 7.2 volts and this will result in marginal performance. See Figure 4 for a suggested arrangement.

A complete kit of all the parts that mount on the PC board, including a drilled, etched, and screened board is available from the source mentioned in the Parts List. A suitable case and other hardware is also available. **NV**

BIPOLAR TRANSISTOR COOKBOOK — PART 2

Ray Marston describes a variety of practical common-collector amplifier circuits in this month's episode of an eight-part series.

by Ray Marston

Last month's article gave an introductory outline of bipolar transistor principles, characteristics, and basic circuit configurations. This month's article concentrates on practical ways of using bipolar transistors in useful common-collector (voltage follower) circuit applications.

COMMON-COLLECTOR AMPLIFIER CIRCUIT

The common-collector amplifier (also known as the grounded-collector amplifier, emitter follower, or voltage follower) can be used in a wide variety of digital and analog amplifier and constant-current generator applications. This month we start off by looking at practical "digital" amplifier circuits.

DIGITAL AMPLIFIERS

Figure 1 shows a simple npn common-collector digital amplifier in which the input is either low (at zero volts) or high (at a V_{peak} value not greater than the supply rail value). When the input is low, Q1 is cut off and the output is at zero volts. When the input is high, Q1 is driven on and current I_L flows in R_L, thus generating an output voltage across R_L — intrinsic negative feedback makes this output voltage take up a value one base-emitter junction volt-drop (about 600mV) below the input V_{peak} value. Thus, the output voltage "follows" (but is 600mV less than) the input voltage.

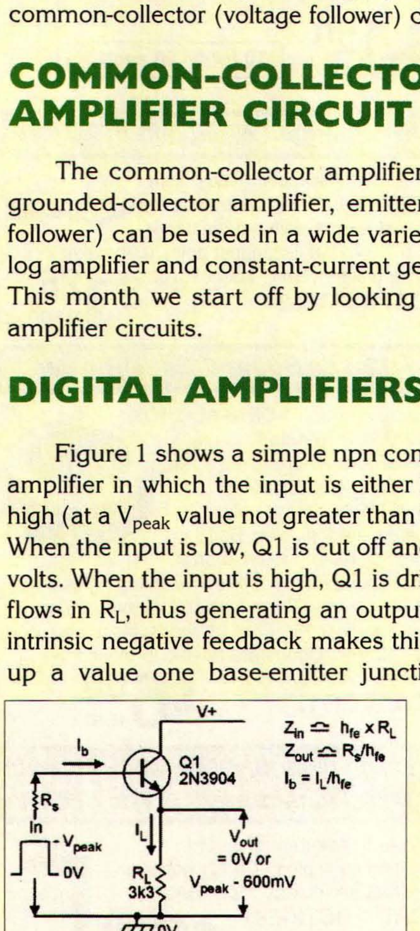


Figure 1. Common-collector digital amplifier basic details.

This circuit's input (base) current equals the I_L value divided by Q1's h_{fe} value (nominally 200 in the 2N3904), and its input impedance equals h_{fe} x R_L, i.e., nominally 660k in the example shown. The circuit's output impedance equals the input signal source impedance (R_s) value divided by h_{fe}. Thus, the circuit has a high input and low output impedance, and acts as a unity-voltage-gain "buffer" circuit.

If this buffer circuit is fed with a fast input pulse, its output may have a deteriorated falling edge, as shown in Figure 2. This deterioration is caused by the presence of stray capacitance (C_s) across R_L. When the input pulse switches high, Q1 turns on and rapidly "sources" (feeds) a charge current into C_s, thus giving an output pulse with a sharp leading edge. However, when the input signal switches low again, Q1 switches off and is thus unable to "sink" (absorb) the charge current of C_s, which thus discharges via R_L and makes the output pulse's trailing edge decay exponentially, with a time constant equal to the C_s-R_L product.

Note from the above description that an npn emitter follower can efficiently source (but not sink) high currents — a pnp emitter follower gives the opposite action, and can efficiently sink (but not source) high currents.

RELAY DRIVERS

If the basic Figure 1 switching circuit is used to drive inductive loads such as coils or loudspeakers, etc., it must be fitted with a diode protection network to limit inductive switch-off back-EMFs to safe values. One very useful inductor-driving circuit is the relay driver, and a number of examples of this are shown in Figures 3 to 7.

The relay in the npn driver circuit in Figure 3 can be activated via a digital input or via switch SW1 — it turns on when the input signal is high or SW1 is closed, and turns off when the input signal is low or SW1 is open. Relay contacts RLA/1 are available for external use, and the circuit can be made self-latching by wiring a spare set or normally-open relay contacts (RLA/2) between Q1's collector and emitter, as shown dotted. Figure 4 is a pnp version of the same circuit; in this case, the relay can be turned on by closing SW1 or by applying a "zero" input signal. Note in Figure 3 that D1 damps relay switch-off back-emfs by preventing this voltage from swinging below the zero-volts rail value. Optional diode D2 can be used to stop this voltage

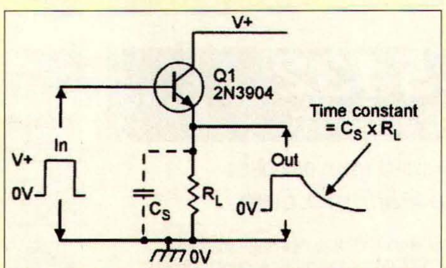


Figure 2. Effects of C_S on the circuit's output pulses in Figure 1.

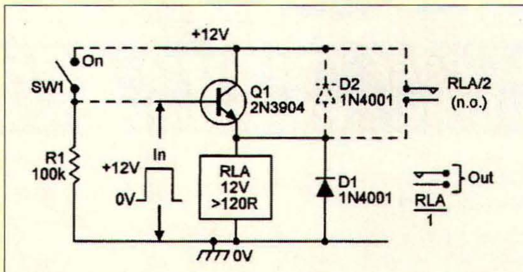


Figure 3. Simple emitter-follower relay driver.

swinging above the positive rail.

The circuits shown in Figures 3 and 4 effectively increase the relay current sensitivity by a factor of about 200 (the h_{fe} value of Q1), e.g., if the relay has a coil resistance of 120R and needs an activating current of 100mA, the circuit's input impedance is 24k and the input operating current requirement is 0.5mA. Sensitivity can be further increased by using a Darlington pair of transistors in place of Q1 (as shown in Figure 5), but the emitter "following" voltage of Q2 will be 1.2V (two base-emitter volt drops) below the base input voltage of Q1. This circuit has an input impedance of 500k and needs an input operating current of 24µA – C1 protects the circuit against activation via high-impedance transient voltages, such as those induced by lightening flashes, RFI, etc. The Darlington buffer is useful in relay-driving C-R time-delay designs such as those shown in Figures 6 and 7, in which C1-R1 generate an exponential waveform that is fed to the relay via Q1-Q2, thus making the relay change state some delayed time after the supply is initially connected. With an R1 value of 120k, the circuits give operating delays of roughly 0.1 seconds per µF of C1 value, i.e., a 10 second delay if C1 = 100µF, etc. The Figure 6 circuit makes the relay turn on some delayed time after its power supply is connected. The Figure 7 circuit makes the relay turn on as soon as the supply is connected, but turn off again after a fixed delay.

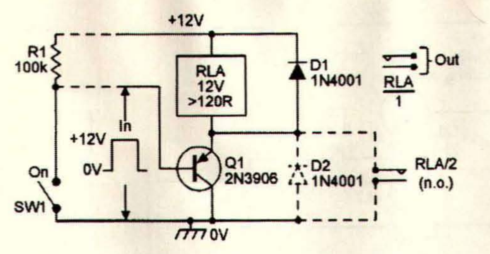


Figure 4. Pnp version of the relay driver.

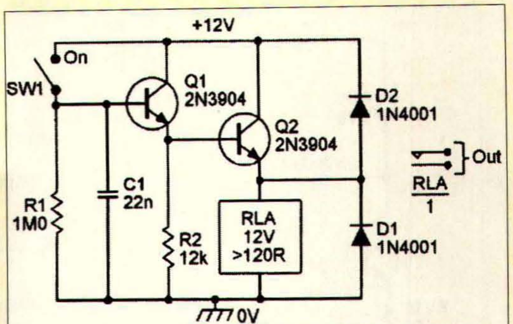


Figure 5. Darlington version of the npn relay driver.

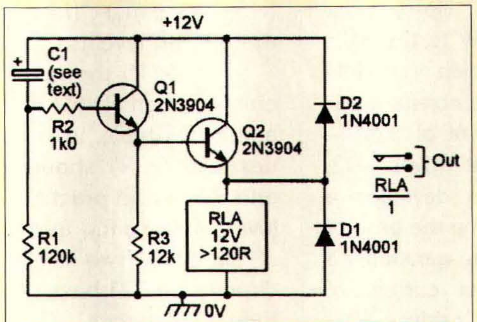


Figure 7. Auto-turn-off time-delay circuit.

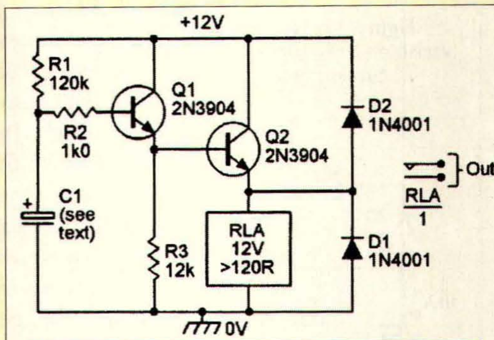


Figure 6. Delayed switch-on relay driver.

CONSTANT-CURRENT GENERATORS

A constant-current generator (CCG) is a circuit that generates a constant load current irrespective of wide variations in load resistance. A bipolar transistor can be used as a CCG by using it in the common-collector mode shown in Figure 8. Here, R1-ZD1 applies a fixed 5.6V "reference" to Q1 base, making 5V appear across R2, which thus passes 5mA via Q1's emitter. A transistor's emitter and collector currents are inherently almost identical, so a 5mA current also flows in any load connected between Q1's collector and the positive supply rail, provided that its resistance is not so high that Q1 is driven into saturation.

These two points thus act as 5mA "constant-current" terminals. This circuit's constant-current value is set by Q1's base voltage and the R2 value, and can be altered by varying either of these values. Figure 9 shows how the basic circuit can be "inverted" to give a ground-referenced, constant-current output that can be varied from about 1mA to 10mA via RV1.

In many practical CCG applications, the circuit's most important feature is its high dynamic output impedance or "current constancy" – the precise current magnitude being of minor importance – in such cases the basic Figure 8 and 9 circuits can be used. If greater precision is needed, the "reference" voltage accuracy must be improved. One way of doing this is to replace R1 with a 5mA constant-current generator, as indicated in Figure 10 by the "double circle" symbol, so that the zener current (and thus voltage) is independent of supply voltage variations. A red LED acts as an excellent reference voltage generator, and has a very low temperature coefficient, and can be used in place of a zener, as shown in Figure 11. In this case, the LED generates roughly 2.0V, so only 1.4V appears across R1, which has its value reduced to 270R to give a constant-current output of 5mA. The CCG (constant-current generator) circuits in Figures 8 through 11 are all "three-terminal" designs that need both supply and output connections. Figure 12 shows a two-terminal CCG that consumes a fixed 2mA when wired in series with an exter-

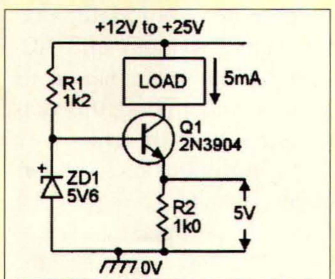


Figure 8. Simple 5mA constant-current generator.

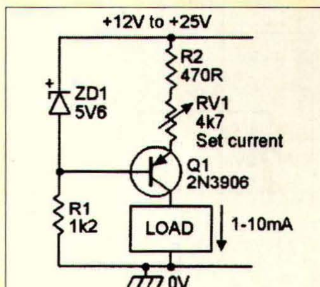


Figure 9. Ground-referenced variable (1mA-10mA) constant-current generator.

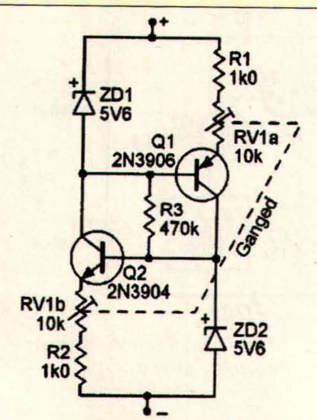


Figure 13. Two-terminal variable (1mA-10mA) constant-current generator.

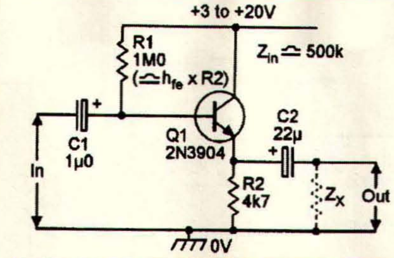


Figure 14. Simple emitter follower.

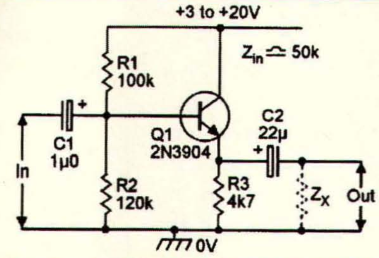


Figure 15. High-stability emitter follower.

nal load. Here, ZD1 applies 5.6V to the base of Q1, which (via R1) generates a constant collector current of 1mA — this current drives ZD2, which thus develops a very stable 5.6V on the base of Q2 which, in turn, generates a constant collector current of about 1mA, which drives ZD1. The circuit thus acts as a closed-loop current regulator that consumes a total of 2mA. R3 acts as a start-up resistor that provides the transistor with initial base current. Figure 13 shows a version of the two-terminal CCG in which the operating current is fully variable from 1mA to 10mA via dual ganged variable resistor RV1. Note that these two circuits each need a minimum operating voltage, between their two main terminals of about 12V, but can operate with maximum ones of 40V.

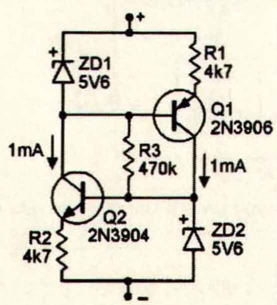


Figure 12. Two-terminal 2mA constant-current generator.

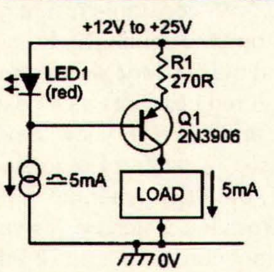


Figure 11. Thermally-stabilized constant-current generator, using an LED as a voltage reference.

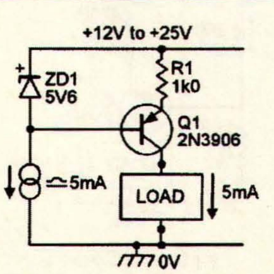


Figure 10. Precision constant-current generator.

LINEAR AMPLIFIERS

A common-collector circuit can be used as an AC-coupled linear amplifier by biasing its base to a quiescent half-supply voltage value (to accommodate maximal signal swings) and AC-coupling the input signal to its base and taking the output signal from its emitter, as shown in the basic circuits in Figures 14 and 15. Figure 14 shows the simplest possible version of the linear emitter follower, with Q1 biased via a single resistor (R1). To achieve half-supply biasing, R1's value must (ideally) equal Q1's input resistance — the biasing level is thus dependent on Q1's h_{fe} value.

Figure 15 shows an improved version of the basic circuit in which R1-R2 applies a quiescent half-supply voltage to Q1 base, irrespective of variations in Q1's h_{fe} values. Ideally, R1 should equal the paralleled values or R2 and R_{IN}, but in practice, it is adequate to simply make R1 low relative to R_{IN}, and to make R2 slightly larger than R1.

In these two circuits, the input impedance looking directly into Q1 base equals h_{fe} x Z_{load}, where (in the basic Figure 14 circuit) Z_{load} is the parallel impedance of R2 and external output load Z_X. Thus, the base impedance value is roughly 1M0 when Z_X is infinite. The input impedance of the complete circuit equals the parallel impedances of the base impedance and the bias network. The circuit in Figure 14 gives an input impedance of about 500k, and the circuit in Figure 15 is about 50k. Both circuits give a voltage gain (A_V) that is slightly below unity, the actual gain being given by:

$$A_V = Z_{load}/(Z_b + Z_{load})$$

where Z_b = $25/I_c$ ohms, and where I_c is the collector current (which is the same as the emitter current) in mA. Thus, at an operating current of 1mA these circuits give a gain of 0.995 when Z_{load} = 4k7, or 0.975 when Z_{load} = 1k0.

BOOTSTRAPPING

The Figure 15 circuit's input impedance can easily be boosted by using the basic "bootstrapping" technique shown in Figure 16. Here, 47k resistor R3 is wired between the R1-R2 biasing network junction and Q1 base, and the input signal is fed to Q1 base via C1. Note, however, that Q1's output is fed back to the R2-R2 junction via C2, and near-identical signal voltages thus appear at both ends of R3 — very little signal current flows in R3, which appears (to the input signal) to have a far greater impedance than its true resistance value.

All practical emitter followers give an A_V of less than unity, and this value determines the resistor "amplification factor," or A_R of the circuit, as follows:

$$A_R = 1/(1 - A_V)$$

Thus, if the circuit has an A_V or 0.995, A_R equals 200 and the R3 impedance is almost 10M. This impedance is in parallel with R_{IN}, so the Figure 16 circuit has an input impedance of roughly 900k. The input impedance of the

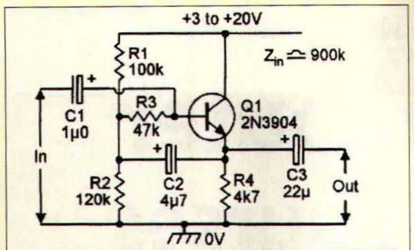


Figure 16. Bootstrapped emitter follower.

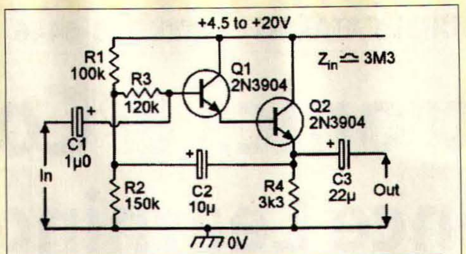


Figure 17. Bootstrapped Darlington emitter follower.

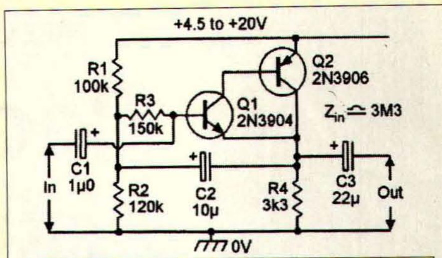


Figure 18. Bootstrapped complementary feedback pair.

circuit in Figure 16 can be increased even more by using a pair of Darlington-connected transistors in place of Q1, and increasing the value of R3, as shown in Figure 17, which gives a measured input impedance of about 3M3.

An even greater input impedance can be obtained by using the bootstrapped "complementary feedback pair" circuit in Figure 18, which gives an input impedance of about 10M. In this case, Q1 and Q2 are, in fact, both wired as common emitter amplifiers, but they operate with virtually 100 percent negative feedback and give an overall voltage gain of almost exactly unity — this "pair" of transistors thus acts like a near-perfect Darlington emitter follower.

COMPLEMENTARY EMITTER FOLLOWERS

It was pointed out earlier that an npn emitter follower can source current, but cannot sink it, and that a pnp emitter follower can sink current, but cannot source it; i.e., these circuits can handle unidirectional output currents only. In many applications, a "bidirectional" emitter follower circuit (that can source and sink currents with equal ease) is required, and this action can be obtained by using a complementary emitter follower configuration in which npn and pnp emitter followers are effectively wired in series. Figures 19 to 21 show basic circuits of this type.

The circuit in Figure 19 uses a dual (split) power supply and has its output direct-coupled to a grounded load (R_L). The series-connected npn and pnp transistors are biased at a quiescent "zero volts" value via the R1-D1-D2-R2 potential divider, with each transistor slightly forward-biased via silicon diodes D1 and D2, which have characteristics inherently similar to those of the transistor base-emitter junctions. C2 ensures that identical input signals are applied to the transistor bases, and R3 and R4 protect the transistors against excessive output currents. The circuit's action is such that Q1 sources current into the load when the input goes positive, and Q2 sinks load current when the input goes negative. Note that input capacitor C1 is a non-polarized type. Figure 20 shows an alternative version of the above circuit, designed for use with a single-ended power supply and an AC-coupled output load — note in this case, that C1 is a polarized type.

THE AMPLIFIED DIODE

The Q1 and Q2 circuits in Figures 19 and 20 are slightly forward-biased (to minimize cross-over distortion problems) via silicon diodes D1 and D2 — in practice, the diode currents (and thus the transistor forward-bias voltages) are usually adjustable over a limited range. If these basic circuits are modified for use with Darlington transistors stages, a total of four biasing diodes are needed — in such cases the diodes are usually replaced by a transistor "amplified diode" stage, as shown by the Q5 circuit in Figure 21.

In the Figure 21 circuit, Q5's collector-to-emitter voltage equals the Q5 base-emitter volt drop (about 600mV) multiplied by (RV1+R3)/R3 — so, if RV1 is set to zero ohms, 600mV are developed across Q5, which thus acts like a single silicon diode. However, if RV1 is set to 47k, about 3.6V is developed across Q5, which thus acts like six series-connected silicon diodes. RV1 can be used to precisely set the Q5 volt drop and thus adjust the quiescent current values of the Q2-Q3 output stages.

High-power versions of the basic Figure 21 circuit are widely used as the basis of many modern "Hi-Fi" audio power amplifier circuits. Some simple circuits of this type will be described later in this Bipolar Transistor Cookbook series. **NV**

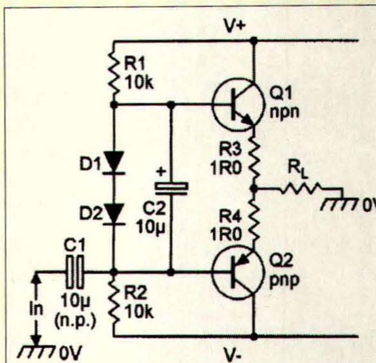


Figure 19. Complementary emitter follower using split supply and direct-coupled output load.

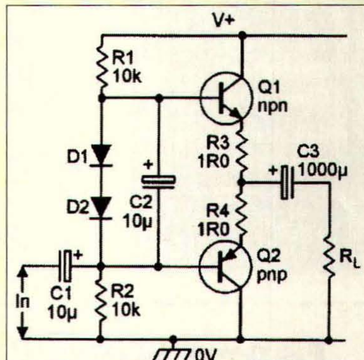


Figure 20. Complementary emitter follower using single-ended supply and AC-coupled load.

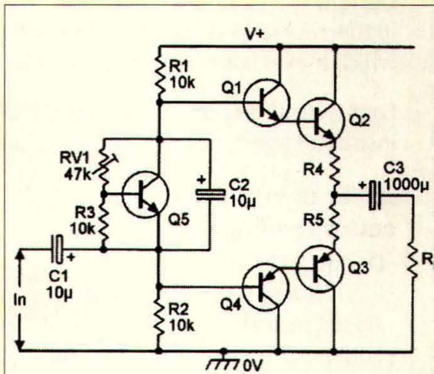


Figure 21. Darlington complementary emitter follower, with biasing via an amplified diode (Q5).

Digitally Programmable Potentiometer (DPP) Basics

Learn the basics!

Tackle those DPPs — including the block diagrams, data sheet parameters, and applications.

by Chuck Wojslaw

The digitally-programmable potentiometer (DPP) is a mixed signal, system-level control device performing a component-level function. The potentiometer adds variability to the analog circuit, while the digital controls add programmability. The DPP brings the high speed, programming, computation, and control of a processor to the variation of the potentiometer in a wide array of analog applications.

Definitions and Block Diagrams

The potentiometer is a three-terminal variable resistance divider device whose schematic symbol is shown in Figure 1. The potentiometer is a passive component and comes in two types: mechanical and electronic. The terminals of the problematic mechanical potentiometer are called CW (clockwise), CCW (counter clockwise), and wiper. The most common corresponding names or designations for the terminals of the electronic version are R_H, R_L, and the wiper R_W. The high and low designations of the terminals are used for wiper direction purposes — the terminals are interchangeable. The mechanical pot is a three-terminal device, while the electronic potentiometer is an integrated circuit with a minimum of eight terminals.

The digitally-programmable potentiometer (DPP) is an electronic potentiometer whose wiper position is computer or digitally controlled. The electronic version of the potentiometer has a memory where wiper settings can be stored. The DPP is a system-level control device performing a component-level function — this idea is illustrated in Figure 2A. The implementation of the analog potentiometer in the mixed-signal integrated circuit is shown in Figure 2B. Polycrystalline resistors are connected in series between the R_H and R_L terminals, and solid-state switches implemented by pMOS, nMOS, or CMOS transistors are connected at each end of this resistor array, as well as between the resistors. The switches are equivalent to a single pole, single throw switch. One end of all the switches are tied together and are connected to the wiper terminal. Only one switch will be closed at a time connecting a node in the series resistor array to the wiper. The resistors are polycrystalline silicon deposited on an oxide layer to insulate them from the other circuitry.

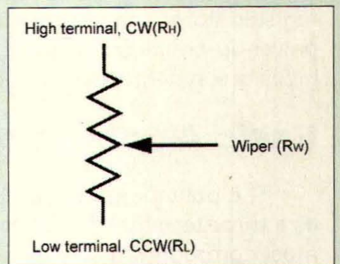


Figure 1. Schematic symbol of the potentiometer.

The Digital Controls

The block diagram of a typical DPP is shown in Figure 3. The control and memory section of the device is implemented in CMOS and is typically biased with a 3V or 5V (2.5V-6V) digital or logic supply. The device is controlled through one of several different serial buses. The more common serial buses are:

(1) Increment/decrement
(2) I^2C
(3) SPI (Serial Peripheral Interface)
(4) Microwire-like

The control signals for the increment/decrement asynchronous bus are Up//Down, /Increment, and /Chip Select. The Up//Down control input is a level-sensitive signal which establishes the direction of the movement of the wiper. The wiper is moved on the falling edge of the Increment control input in the direction established by the Up/Down signal. The /Chip Select control input is like an

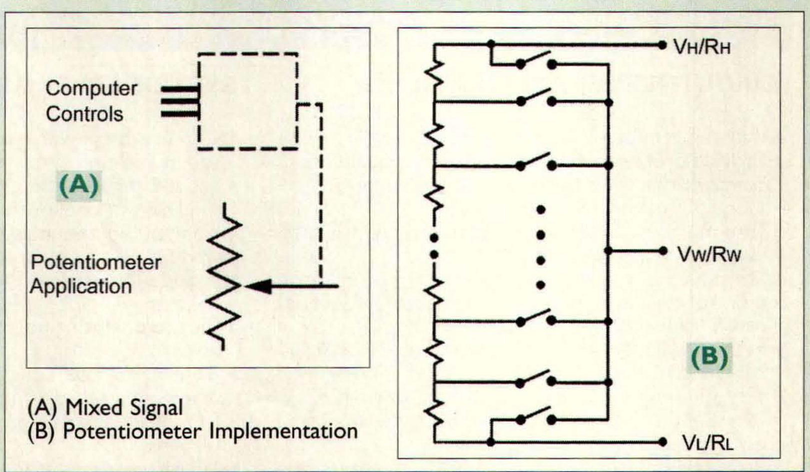


Figure 2. Digitally-programmable potentiometer.

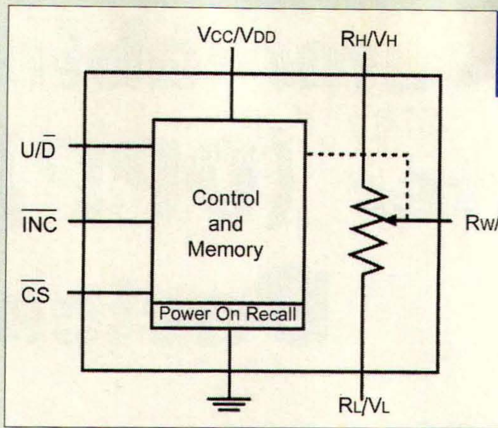


Figure 3. Block diagram.

address line and enables or disables the device. For the DPPs with an increment/decrement interface, there is only one internal nonvolatile register per potentiometer — the register stores the wiper setting for restoration during the power-up condition. The I^2C, SPI, and microwire-like interfaces are synchronous and have protocols.

Basic Application Modes

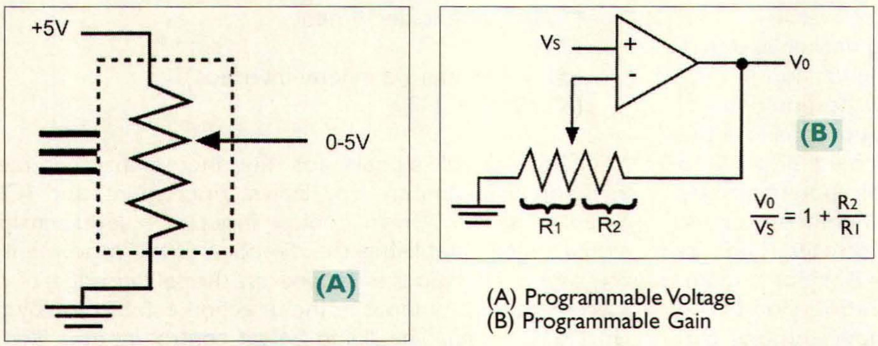
The potentiometer can be used in application circuits as a three-terminal device or as a two-terminal device. The most common way to use the potentiometer as a three-terminal device — seen in Figure 4A — is as a voltage divider circuit. Plus and/or minus voltages are connected across the potentiometer and the wiper goes from one voltage limit to the other as the wiper is moved from the low to high terminals. In many applications, this circuit can be substituted for a digital-to-analog converter since it performs a digital in/analog out function. The variability of the wiper-to-low and wiper-to-high resistances of the potentiometer can be used to add variability to analog functions, like the non-inverting amplifier circuit shown in Figure 4B.

The second fundamental way of using the DPP is as a two-terminal, variable resistance. A simple application illustrating this configuration is shown in Figure 5A where the potentiometer functions as a variable resistor and, in essence, varies the current through the diode since the voltage across the potentiometer is relatively constant. The variation of R in Figure 5B allows the cut-off frequency of the high pass filter to be programmed. The two basic applications (Figures 4A and 5A) illustrate the use of the digitally programmable potentiometer in a digital-to-analog voltage circuit and in a digital-to-analog current circuit.

Circuit and System Level Applications

The DPP performs a basic component-level function and can be found in a very broad range of applications at both the circuit and system levels. Figure 6 lists some of these applications. DPPs control voltage, current, resistance, frequency, power, capacitance, bandwidth, Q, duty cycle, gain, etc.

Wherever there is a resistance which defines a system parameter, the DPP becomes a candidate to vary and control that parameter. As an example, the DPP can be used to control the duty cycle of a PWM (pulse width modulator). The PWM, in turn, can be used to control the speed of a robot's motor, or it can be used as the key control element in a switching power supply.



(A) Programmable Voltage
(B) Programmable Gain

Figure 4. Basic applications — three-terminal device.

For the designer, the electronic potentiometer is a superior component because it is digitally-controlled, programmable, flexible, and has a small size and low weight. In the manufacturing area, the electronic potentiometer is low-cost, reliable, compatible with automated assembly techniques, has a short test time, and has low field service costs.

The wiper-to-low and wiper-to-high resistances of the potentiometer, shown in Figure 7, are modeled as (kR_{POT}) and $(1\text{-}k)\ R_{POT}$, where k is a dimensionless number from 0 to 1 and reflects the proportionate position of the wiper from one end (k=0) of the potentiometer to the other end (k=1). When analyzing analog circuits with potentiometers, k will show up in the defining equations of the circuits and provide another degree of freedom for the circuit designer. The potentiometer adds variability and programmabil-

CIRCUIT LEVEL APPLICATIONS

- Vary the gain of a voltage amplifier.
- Provide programmable DC reference voltages for comparators, window detectors, and limiters.
- Control the volume in audio circuits.
- Trim out the offset voltage and bias current errors in a voltage amplifier circuit.
- Set the output voltage of a linear voltage regulator.
- Control the passband gain, characteristic frequency, cutoff frequency, and Q in filter circuits.
- Set the scale factor and zero point in sensor signal conditioning circuits.
- Vary the frequency and duty cycle of timer ICs.
- Vary the DC biasing of a pin diode attenuator in RF circuits.
- Provide a control variable (I, V, or R) in closed loop, feedback circuits.

SYSTEM LEVEL APPLICATIONS

- Control the power level of LED transmitters in communication systems.
- Set and regulate the DC biasing point of power amplifiers in communication systems.
- Control the gain in audio and home entertainment systems.
- Provide the variable DC bias for tuners in RF systems.
- Set the operating points in temperature control systems.
- Control the operating point and linearization scheme for sensors in industrial systems.
- Trim offset and gain errors in artificial intelligent systems.
- Adjust the contrast in LCD displays.

Figure 6.

ity to the analog circuit, and k is a way of assessing the variability on the circuit's performance.

Data Sheet Parameters

The analog data sheet parameters reflect the limitations and characteristics of the digitally-programmable potentiometer. The key analog data sheet parameters are number of taps, end-to-end resistance, maximum voltages on the potentiometer pins, wiper resistance and current, resolution, noise, linearity, and temperature coefficients. Figure 8 lists the data sheet parameters and their values for a typical DPP.

The number of taps in a potentiometer reflects the resolution of the device or its ability to discern 1 of n. Potentiometers used in a summing amplifier circuit can extend the basic resolution of the pot to almost an unlimited number. The end-to-end resistance (R_H to R_L) of the potentiometer is R_{POT} and comes in 1kΩ to 100kΩ values. A low cost, low TC, one percent resistor in parallel with R_{POT} provides the designer with a technique of customizing the pot's end-to-end resistance in most applications. The voltage V_{CC}/V_{DD}, 2.5V to 6V, provides the voltage biasing for the digital control and memory section. The voltages $V_{TERMINAL}$ or V_{RH}/V_{RL} are the maximum voltages that can be applied to the potentiometer pins in their application. Wiper resistance models the resistance r_{ds} (on) of the MOS switches used to connect the wiper terminal to a node in the resistor array. The wiper current spec, 1-3mA, limits the maximum amount of current allowed through the wiper switches.

Application circuit topologies where the wiper is connected to a high impedance minimize the dependence on the wiper's specs. Absolute linearity describes the actual versus expected value of the potentiometer when used as a divider, and is guaranteed to be accurate within one least significant bit (LSB). Relative linearity describes the tap-to-tap accuracy and is guaranteed to be 0.5 of an LSB. Two parameters describe the temperature dependence of R_{POT} and the resistances in the series array. R_{POT} TC (temperature coefficient) is a nominal 300ppm/°C and the ratiometric TC is guaranteed to be within 20ppm/°C. While the data sheet parameters reflect the performance limitations of the digitally-controlled potentiometer, there are a large number of circuit techniques that minimize these limitations. Application notes and technical briefs describe these techniques and are available at Catalyst Semiconductor's website **www.catalyst-semiconductorcatsemi.com**. **NV**

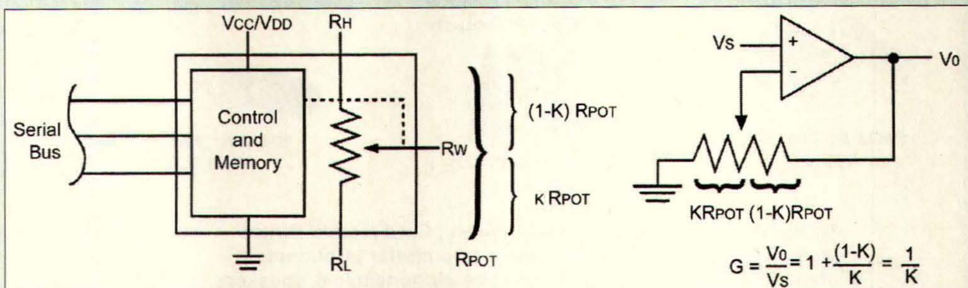
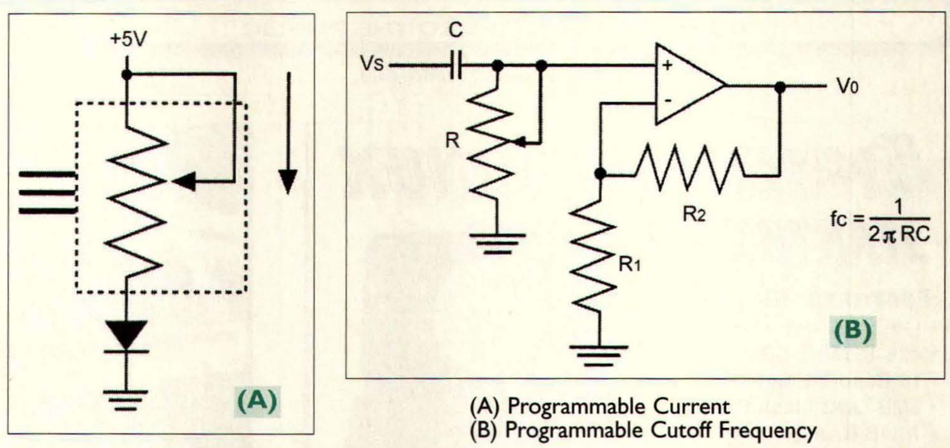


Figure 7. Modeling potentiometer resistance.



(A) Programmable Current
(B) Programmable Cutoff Frequency

Figure 5. Basic applications — two-terminal device.

Figure 8. Data Sheet Parameters.

CAT5114 POTENTIOMETER PARAMETERS

Symbol	Parameter	Conditions	Min	Typ	Max	Units
R_{POT}	Potentiometer Resistance	-10 Device		10		kΩ
		-00 Device		100		
	Pot Resistance Tolerance				±15	%
V_{RH}	Voltage on R_H pin		0		Vcc	V
V_{RL}	Voltage on R_L pin		0		Vcc	V
	Resolution			3.2		%
INL	Integral Linearity Error	Iw ≤ 2μA		0.5	1	LSB
DNL	Differential Linearity Error	Iw ≤ 2μA		0.25	0.5	LSB
R_{Wi}	Wiper Resistance	Vcc = 5V, Iw = 1mA			400	Ω
		Vcc = 2.5V, Iw = 1mA			1	kΩ
Iw	Wiper Current				1	mA
TC_{RPOT}	TC of Pot Resistance			TBD		ppm/°C
TC_{RATIO}	Ratiometric TC			TBD		ppm/°C
R_{ISO}	Isolation Resistance			TBD		Ω
V_N	Noise			TBD		nV/√Hz
$C_H/C_L/C_W$	Potentiometer Capacitances			8/8/25		pF
fc	Frequency Response	Passive Attenuator		1.4		MHz

Continued from Page 6

look to be 1/4 or 1/2 inch thick per sheet! I just want readers to be very careful when reading these sizes, using the wrong system is part of what destroyed a Mars probe and can cause havoc with user projects.

Richard Detlefsen
via Internet

Response:

The reference to "mil" appears to be somewhat widespread in the plastics industry, where they refer to the material in question as "3 mil," or "6 mil," and yes, it's millimeters when talking about rigid sheet plastic. The text is from the context of what a customer may encounter when purchasing the material, and the terminology this particular industry uses, even if the terminology is mis-applied.

I realize it's incorrect, but I've encountered it at a number of plastics outlets, so I wanted to introduce the term to help readers find what they wanted. I don't have the text of the sidebar handy, but I don't remember saying 1 mil = 1mm but, if so, that would be wrong as a generic statement.

Gordon McComb

Dear Nuts & Volts:

I've built the low-power version of Randy Slone's CF-MOSFET audio power amp (*N & V* Feb. and Mar. '03) and it sounds wonderful! I redid the circuit board to be about 47% smaller because I wanted to fit two amps and their power supply into a rack mount case 5-1/4 inch high by 10 inches deep (a Sescom 4RU10). I used a Avel toroidal power transformer (type D4052) for an input to the amps of plus and minus 50 VDC. Please note that the new circuit board layout may not be suitable for the high-power version as I used some 1/4-watt metal film resistors instead of all 1/2-watt resistors. For those who are interested, I'm posting the new card layout and revised parts list on my web site (**www.zianet.com/tdl**) in the Magazine Article section.

Ron Tipton
via Internet

Dear Nuts & Volts:

Was I surprised to see an article on the Forth Programming Language *N & V* July 03. I thought it was dead.

When it first came out I was sure it would be the programming language of the future. I bought two books on it, but I had trouble getting decent programming software. This was Forth, Inc.'s blunder. They had total control of the language and sold a license for $2,000.00. They should have prepared study guides (Forth for Idiots?) and a series of tutorial manuals.

Forth is the fastest language going except for pure machine language. There are some FIG groups out there (Forth Interest Group) and some dedicated programmers who can't talk anything, but Forth. I threw my two books out when I couldn't bridge from the theoretical to anything practical. I plan to study your article and possibly jump-start my interest.

Bob Ziller
New Richmond, WI

Dear Nuts & Volts:

I *love* your magazine. I'm a robotics addict and your publication is excellent. I will be subscribing.

Jim G.
via Internet

Continued on Page 72

SOFTWARE FOR AUDIO TESTING

Perform audio testing with these "virtual" instruments, and go easy on the pocketbook!

by Ron Tipton

Traditional audio testing is done with a variety of lab instruments. A signal generator's output is applied to the input of the device under test (DUT) and its output is examined with an oscilloscope, distortion analyzer, spectrum analyzer, etc., depending on what characteristics are wanted about the DUT. The DUT can be any active or passive network, such as an amplifier or filter. It can also be the acoustical properties of a room or the sound attenuation of a wall. These test set-ups are shown graphically in Figures 1a and 1b. Some time ago, I set out to look at how much of this work could be done with a personal computer and a sound card. I've learned that many of the usual lab instruments can be replaced with "virtual instrument" software that ranges in price from free to moderate. However, I found that price is not always a measure of quality. One of the best programs I found is low-cost shareware. In this article, I want to share my evaluation and comparisons with you.

There is one downside to using virtual instruments, and that is the sound card itself. In order to use the card's full dynamic range, the peak input level must be set just below the point where the analog-to-digital converter (ADC) is overdriven. Depending on the gain or loss of the DUT, you may have to add attenuation or gain in the signal path to keep your sound card's input level where it needs to be. This means having to know the characteristics of the added devices so their effect can be calibrated out. In addition, you need to know a lot about your sound card, so we'll look at that next.

SOUND CARDS

Sound cards are not created equal. There is a lot of variation in quality, with the better cards usually being higher priced. However, if you shop around, you can find several good cards for less than $100.00. Fortunately, Mr. Arnold B. Krueger evaluates sound cards and posts the information on his web site [1]. He updates his data frequently to keep up with the introduction of new models. Oddly (to my thinking), the best cards have the lowest score. He rates frequency response, 1 kHz THD, SNR, IM, dynamic range, and jitter in six steps from excellent to bad. (Please see the Glossary for unfamiliar terms.) The best cards have a score of five and rate excellent in all categories. The Turtle Beach Santa Cruz card has a score of seven with three excellents and three very goods. The "street price" is about $80.00. and all the software evaluations in this article were made with the Santa Cruz.

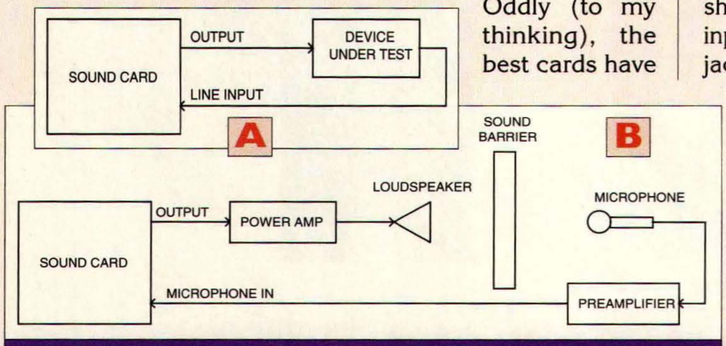


Figure 1. A) Testing an active or passive network. Attenuators or amplifiers may be needed in the signal path to keep the line input level at the optimum value. B) Testing with a loudspeaker and microphone. This setup can also be used to test the loudspeaker or its enclosure.

Although some of the software will perform post processing, that is, analyze a recorded file, I included only programs that do real-time analysis because that's how lab instruments work. So I didn't include programs such as DADiSP [2] or MathCAD [3]. Undoubtedly these are useful, but not for real-time audio measurements. I also didn't include software that costs $1,000.00 or more, such as Clio [4] and SYSid-Labs [5]. As fine as they may be, they are out of my range. If your budget can take it, you may want to check them out.

You also need to calibrate your sound card's line input. That is, you need to know the maximum input level that avoids overdriving the ADC. Some programs contain an integrated way to perform the calibration, but I'll describe a general method that requires only a physical voltmeter, virtual (or physical) signal generator, and a virtual spectrum analyzer. I've summarized my findings in Table 1 to give you an overview and also for quick reference. Let's start our discussion with the third table line (AudioTester) which I rate a Best Buy. It's rich with features and easy to learn. For $28.00 — you shouldn't be without it!

AUDIO TESTER

This package of three integrated programs (wave generator, 'scope, and spectrum analyzer) includes a built-in calibrator to set the optimum input level. You can follow the on-screen instructions, so I won't repeat them here. Instead, I'll cover the general method I mentioned earlier and then go on to a practical example — testing a tunable filter.

Begin by building the circuit shown in Figure 2 in a shielded box. It's useful to have left and right outputs and inputs for testing and it avoids wear on your sound card's jacks. Connect the left output to both the left and right inputs, as well as to an AC voltmeter. The optimum input level is typically 200 to 600 millivolts (mV) RMS so your voltmeter should have adequate resolution in that range. Launch your sound card control panel (the little speaker in the lower right corner). Select line-in and mute the other inputs. Set the line-in gain to maximum and the master volume slider to about midrange.

Start AudioTester — you'll see the spectrum analyzer and the analyzer's control panel as separate screens. Arrange them one above the other and then click the Signal Generator tab. Pull the generator control panel off to one side and then return to the spectrum analyzer by clicking its tab. Select 1,000 Hz and sinewave. Set the "L" and "R" sliders to 0 or -1 dB and then click Start. On the analyzer panel, choose a Blackman-Harris window, 4K FFT length, 44.1 kHz sample rate, 16-bits, and then click Start. You should see a trace at one kHz on the analyzer screen, and you should have a reading on the voltmeter. Your goal is to set the master volume level (generator panel slider labeled Ana) to minimize the THD+N. If the level is too high, you will also get an OVER displayed in the Input area on the analyzer control panel.

You can accomplish this and get the same results by using NCH Tone as the signal generator and Spectrogram as the analyzer. Spectrogram doesn't have a built-in THD measurement, so you have to adjust the line-in level to minimize the heights of the harmonics compared to the one kHz amplitude. (You can calculate the THD with program thd.exe [6].) I have compared all the software analyzers in Table 1 to a physical analyzer (a Hewlett-Packard model 3581A) and they all agree to within a few dB. This convinces me that I can rely on the accuracy of the virtual instruments. Now on to a practical example.

Program Name	Version	Type	Signal Gen	'Scope	Spectrum Analyzer	Post Processor	Comments
At Spec Pro **www.taquis.com**	2.2	Shareware $95.00	Yes	Yes	Yes	Yes	Very nice. Does not have sweep freq., in signal generator, but pink noise does a good job displaying response curves. Shareware version somewhat limited.
Audio Meter Pinquin **www.masterpinguin.de**	PG-S 2.2	Commercial $245.00	No	Yes	Yes	No	Has digital peak meter, stereo meter, and correlation meter. Apparently no choice of FFT length.
AudioTester **www.audiotester.de**	1.4h	Shareware $28.00	Yes	Yes	Yes	Yes	Selectable input filter, up to 140 dB dynamic range, windowing, FFT size to 16K points, THD+N, lots more. A best buy. (Updates are free.)
NCH Tone **www.nch.com.au**	1.03	Shareware $36.00	Yes	No	No	No	1 Hz to 22 KHz sine, square, triangle, saw, impulse, white noise. Log and linear sweep. Sound card out and wav file for settable time duration.
Sample Champion Pro **www.purebits.com**	2.8	Commercial $325.00 plus plugins	Yes	Yes	Yes	Yes	Very complete package. I found it a bit hard to learn so I printed the 90-page User Manual (pdf file) and followed the examples. This one grows on you the more you use it; I have a licensed copy.
SpectraPlus **www.spectraplus.com**	2.3.2	Commercial $299.00 plus plugins	Yes	No	Yes	Yes	Choice of window, FFT size to 32K, THD, THD+N (with plugin), 100 dB range, octave, 1/3 octave, spectrogram, 3D surface. Excellent program.
Spectrogram **www.visualizationsoftware.com/gram.html**	7.2	Shareware $45.00 ($25.00 if student)	No	No	Yes	Yes	No window choice, FFT size to 16K, 90 dB range. Also 1/2 octave. Very easy to use.
TrueRTA **www.trueaudio.com**	2.0.1	$99.95 for all features	Yes	Yes	Yes	No	Octave-band analyzer only version is free. Very useful program, see write up in the article. I have licensed the full-featured version.
Wavetools **www.mda-vst.com**		Freeware	Yes*	Yes*	Yes*	Yes	* Separate programs. Analyzer and scope screens small and not resizable, but can put data on clipboard. No sweep freq., but has pink and white noises — and it's free!

TABLE 1. Comparison of virtual audio instrument software evaluated for this article.

A TUNABLE FILTER

Some time ago, I rebuilt an SKL model 302 Tunable Filter [7]. I replaced the original vacuum tube circuits with op-amps, decreasing the weight, power consumption, and output noise level. I thought this filter would make a good DUT. I could look at a frequency response, THD+N, and output with no input signal.

The sweep frequency generator in AudioTester has an especially useful feature. If the right output line is looped back to the left line-in, the frequency response of the sound card is compensated out. Referring to Figure 2, I connected the right output line to the filter's input and to left line-in. I connected the filter's output to the right line-in, a voltmeter, and a physical 'scope. I tuned the lowpass filter cutoff frequency to two kHz and the highpass cutoff frequency to 500 Hz. I set the start frequency on the sweep generator to 100 Hz, the stop frequency to 10 kHz, and the number of frequency steps to 50. I clicked Start and got the bandpass response shown in Figure 3. AudioTester will print the screen or save the data in a text file. I chose the text file and then imported it into a graphing program. Using the wave generator set for a one-kHz sinewave, I got the spectrum shown in Figure 4 and a THD+N reading of -71.5 dB, which is 0.0266 percent. With the signal generator off, the one Hz was gone, but the spectrum was otherwise unchanged, so the output noise level is -71.5 dB. Now, let's take a look at making these measurements in a couple of the other programs.

SPECTRAPLUS

SpectraPlus does not feature automatic compensation of the sound card's frequency response, but it does let you perform the compensation. Loop the output back into the line-in with a jumper cable and connect a voltmeter to the line-in to make sure you aren't overloading it. Select the Utilities menu and set up the sweep frequency generator. Set the start and stop frequencies to 20 Hz and 22 kHz and the sweep time to 10 seconds or longer. Select Realtime on the Mode menu. Select 16-bits, mono, 44100 sample rate, a Blackman window, and 4096 FFT length.

Clicking the Spectrum Analyzer Run button will start it and the sweep generator. You should start seeing the response of your sound card on the analyzer screen. It may be flat or it may show a decrease in amplitude at higher frequencies. If it's flat, you don't need a compensation file. But to make a compensation file, stop the analyzer and then click Edit (menu bar) and then Copy. This puts an ASCII table of frequency and response values on the clipboard.

Minimize SpectraPlus and start an editor, such as Notepad, and then paste the clipboard table and save it as a text file. There will be lots of data in this file — more than you need in your compensation file. Edit out most of the lines (or make a new file) and keep only primary points: 20 Hz, 40 Hz, 60 Hz, 80 Hz, 100 Hz, 200 Hz, etc. Put this file in the MICCOMP subdirectory with a file extension of .mic because it's treated as a microphone compensation file. Load it for use by going to Options | Scaling and click the Select button under Microphone Compensation controls. Select the file you just created using the file selection dialog box. Now we're ready to reconnect the SKL Tunable Filter between the output and line-in. I followed the procedure just described to measure the sound card's response. I got the bandpass response on the screen and saved the data with a copy and paste. The plot was so close to the one shown in Figure 3 that I didn't see any need to include it.

Next, I selected a single-tone at one kHz instead of the sweep generator. The spectrum display looked about like Figure 4. I clicked THD and THD+N on the Utilities menu and two small boxes appeared on the right side of the screen displaying the distortion numbers. THD read 0.007 percent and THD+N was 0.062 percent. (The HP 3581A Wave Analyzer read 0.04 percent, about half way between AudioTester and SpectraPlus.) This illustrates the difficulty in making audio measurements on low distortion equipment. It's also the reason I like to have more than one measurement program so I can compare results. Now I'll go through the same measurement with Sample Champion Pro.

SAMPLE CHAMPION PRO

As I mentioned in the Comments in Table 1, Sample Champion Pro (SCP) is different, but the more I use it, the better I like it. AudioTester and SpectraPlus both have a real-time mode; turn on the signal generator and immediately see the frequency spectrum. SCP doesn't work quite the same way. First, you capture a sample of the line-in signal to a 'scope display. Then you select all or a portion of the 'scope waveform, and finally, you perform an FFT to see the spectrum in its own window.

In addition, SCP's signal generator is based on maxi-

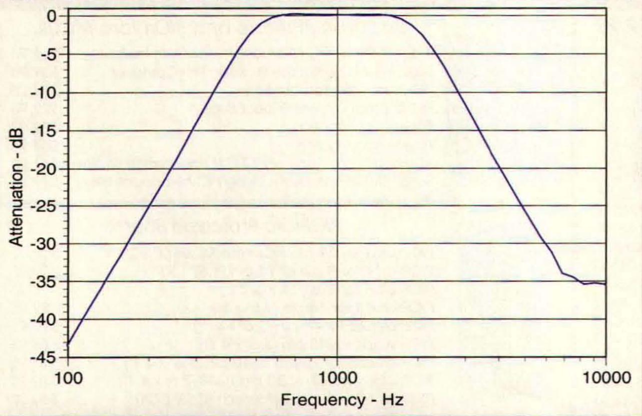


Figure 3. Response of rebuilt SKL-302 Tunable Filter. Lowpass cutoff frequency set to 2 kHz. Highpass frequency set to 500 Hz. Data saved as text file in *Audio Tester* software.

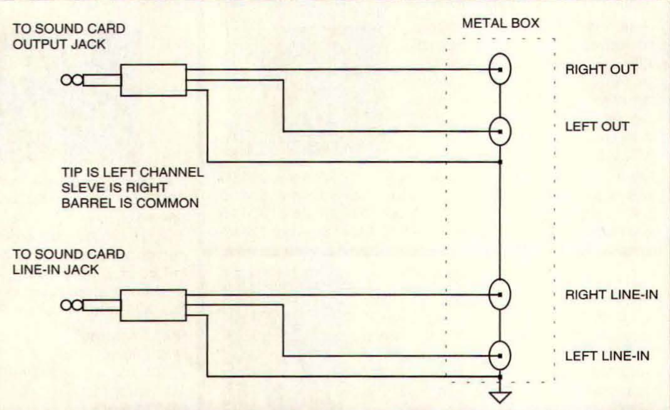


Figure 2. A sound card plug box makes audio testing easier. Use whatever connectors you prefer: audio jacks, BNC, pin jacks, etc.

mal length pseudo-random sequences (MLS), which is a good way to generate pseudo-random noise. (The signal is wide band, but it repeats at a rate dependent on the sequence length and clock rate. Hence the name pseudo-random noise.) This may seem strange to you, but it provides some measurement choices not found in the other programs. For instance, instead of using a sweep generator to measure the tunable filter's response, you can directly measure its impulse response and then FFT it to get the frequency response. The result is a nearly instantaneous bandpass plot that matches Figure 3. (The trial version of SCP does not let you save data to a file.)

A one-kHz tone is available for measuring THD and THD+N and I set this up as follows. I clicked Options | Settings and then selected 16-bits, mono, and a 44100 sample rate in both the Input and Output boxes. I chose a Blackman window and 4096 FFT length. Under "MLS type" I selected Amplitude calibration signal (one-kHz sinewave).

I opened a 'scope window by clicking the Scope Window icon and then I clicked Y Auto Scale. I clicked Measure in the menu bar and then Start/Stop sync Rec/Play. This captures about 100 mS of the one-kHz sinewave in the 'scope window (this time can't be changed in the trial version). I clicked Select All in the 'scope window to use the whole sample. I clicked FFT on the menu bar and then Selection in the Time Window under Spectrum. This displays the one-kHz tone much like Figure 4. I clicked FFT in the menu bar again and then Audio Quality plugin, and finally, the THD/THD+N tab. The THD reading was 0.006 percent and THD+N was 0.14 percent. The THD+N is high, probably because of the short duration of the one-kHz signal which tends to over-emphasize the noise. The level of each harmonic, up to the tenth, is also displayed on a small screen in the THD box.

Although I used the SKL Tunable Filter in all these examples, remember that you can measure any active or passive device that you can connect between your sound card's output and line-in. Let's look at another example.

ACOUSTIC LOSS THROUGH AN INTERIOR DOOR

It's easy to measure the loss through an interior (or exterior) door using the set-up in Figure 5. Just to show you how you can sometimes do a lot for a small price, I used the freeware WaveTools and my "Best Buy" rated AudioTester for this measurement. The procedure is just about the same for both programs. With the door open, start the signal generator using pink noise and start the spectrum analyzer. Adjust the power amplifier input level and microphone preamp gain for a non-overloading voltage on line-in. AudioTester has a red Overload indicator on the analyzer screen and WaveTools displays CLIP if the input level is too high. (You can load a microphone compensation file in AudioTester if you know your mic's frequency response. But WaveTools doesn't have this feature, so I didn't use it in AudioTester either. This demonstrates better agreement between the two programs.)

When you have the "open door" display on the screen, stop the analyzer and copy the data to the clipboard. Open Notepad (or other ASCII text editor), paste, and save the file as "open.txt." Without making any gain changes, close the door and restart the analyzer. Then stop the analyzer and capture the data to "closed.txt" and you are almost

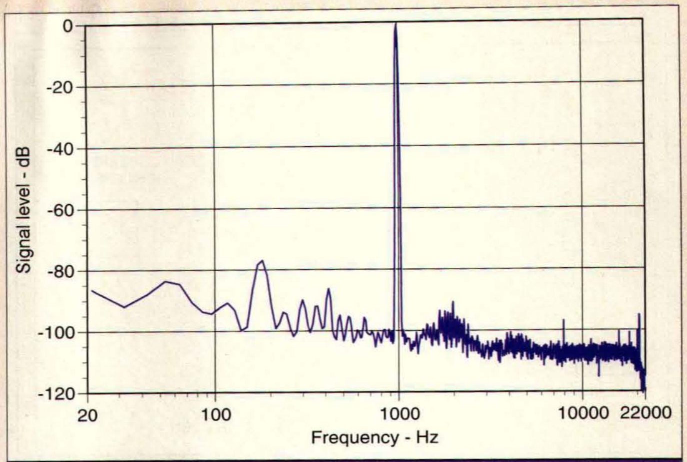


Figure 4. Output spectrum of rebuilt SKL-302 Tunable Filter with 1 kHz sinewave input. Spurious responses are more than 20 dB lower than original vacuum tube circuit.

done. You can import the data into a scientific graphing program or spreadsheet for plotting. My results are shown in Figures 6 and 7, and these are typical. Hollow core interior doors have only a small loss at low frequencies — they are best between about 1 and 10 kHz. Both programs let you average spectra for a smoother display, so set it to at least 20. (You can watch the display change as you vary the averaging number.) As a final example, let's look at one that's easy in theory, but somewhat difficult in practice.

ROOM REVERBERATION TIME

Reverberation Time (RT) is a measure of a room's "liveness" and different times are needed depending on the room's primary use, as shown in Table 2. Reverberation is the persistence of sound in a room after the sound source has been turned off. The time it takes for the sound level to decrease 60 dB is a common measurement and is abbreviated RT60.

To make this measurement, you fill a room with sound

GLOSSARY

Dynamic Range
The difference in amplitude level between the maximum and minimum useful signals. The maximum level is limited by the overload point of the DUT (or the sound card). The minimum level depends on the residual system noise or "noise floor."

FFT — Fast Fourier Transform
The Fourier transform of a time series of amplitude values is a frequency response. The FFT is a method of digitally performing the transformation.

IM — Intermodulation Distortion
The mixing of two or more pure tones in the DUT to produce spurious tones at other frequencies. IM is primarily a test for nonlinear distortion at the highest frequency used in the test.

Jitter
Frequency modulation distortion. That is, short term frequency changes of the test tone by the DUT.

THD — Total Harmonic Distortion
Non-linearity in the DUT produces harmonics of the test signal. That is, a one-kHz tone (the fundamental) would have harmonics at 2 kHz, 3 kHz, 4 kHz, etc. THD is the square root of the sum of the squares of all measurable harmonic voltage levels. THD can be expressed as in dB with respect to the fundamental level or as a percentage of the fundamental level.

THD+N — Total Harmonic Distortion plus Noise
THD as defined above added to the non-harmonic noise (broadband noise) from the DUT.

SNR — Signal-to-Noise Ratio
A dimension less number equal to signal voltage divided by noise voltage or signal power divided by noise power. It can also be expressed in dB by taking 20 * log(SNR) for a voltage ratio or 10 * log(SNR) for a power ratio.

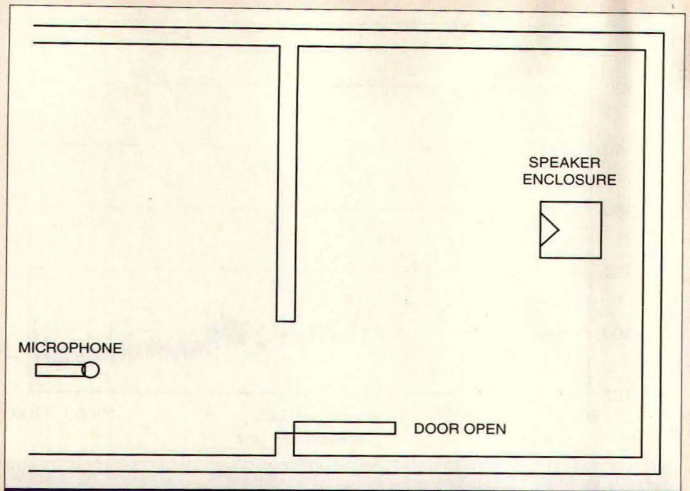


Figure 5. Floor plan of speaker and microphone placement for measuring the increase in sound loss from closing the door. When measuring an exterior wall or door, it's better to place the speaker outside to minimize microphone noise pickup.

from a loudspeaker and pick up the sound with a microphone. Start recording the microphone's output, turn off the sound, and then stop recording. By looking at the recording, you can find the time it took for the level to go down 60 dB, and that's RT60. Ideally, you should use an omnidirectional speaker and omnidirectional microphone to excite all reflecting surfaces, and to pick up all those reflections (called a diffuse sound field). But you can make-do with an ordinary speaker and microphone and your results will be useful, especially if you can move the speaker around and average several measurements. Start with the speaker in a corner, facing the corner about five or six feet away and tilted up about 20°. Place the microphone stand near the center of the room with the microphone oriented so the pick-up is as omnidirectional as possible — this would be vertical, open end up for most mics. You may need a power amplifier to drive the speaker and you will need a mic preamplifier because it's better to use your sound card's line-in, as it usually has a better SNR than the mic input. The problem using the above procedure is getting the needed 60 dB range. The limiting factors are your mic's preamp noise level and the residual room noise. You can lose up to 10 dB of your noise floor from a running refrigerator or fan, or from the wind blowing around the building. Also, you need a very low noise preamp, a high speaker sound level, or both. SCP provides a simple way to make the measurement, but first let's work through doing it the "hard" way.

I couldn't get a 60 dB range, as I didn't want to risk losing a speaker. With SpectraPlus in recording mode, I started the pink noise generator and adjusted the speaker volume for as high of a screen trace as I was comfortable with. Then I stopped the noise generator, and a couple of seconds later I stopped recording. (SpectraPlus has an application note on RT60, so I'm not going to repeat all of the measurement details here.) An unregistered SpectraPlus will make this measurement because it is fully functional. The restriction is a 30-day use limit.

The screen trace clearly showed the level decay from generator turn-off to the noise floor. If this change were 60 dB or more, I'd just use the cursor to measure time and level (in dB) and I'd be finished. But with less than 60 dB, I needed to do some more work. And I found I had some problems. First, the measurement signal is noise, so the screen trace is "noisy" and there isn't any way to average in the recording mode. Second, capturing data to the clipboard in recording mode gave me a WAV file and not level vs. time. So I used a utility program I wrote some time ago — wav2asc [8] — to convert the WAV file to ASCII text. Then I wrote a new program to make all data positive, perform a 100 point moving average, add time values (based on a 44.1 kHz sampling rate), and finally, write all this to a new file. I imported this file into DeltaGraph Pro and fit an exponential curve to the data. The resulting plot, shown in Figure 8, shows an RT60 of about 410 mS. This is a rather "live" room in spite of being carpeted and having an acoustical tile ceiling. One wall is covered with bookcases and storage cabinets with smooth wooden doors. And there is a large cable-weight exercise machine with lots of bare steel reflective surfaces. I didn't know the room was this live, but I'm not surprised by the measurement result.

As I've mentioned, SCP makes this and many other room measurements easy. There is a reverberation time application note in the User Guide, so I won't repeat it all here. But I will address a couple of details. First, you need a registered version with the Room Acoustics plug-in. The trial version won't make this measurement. Second, you start the test by measuring the room's impulse response.

When setting up the signal generator, the peak input level is shown on the right-hand side of the screen. I got the best results with this level at 12 to 15 percent, which

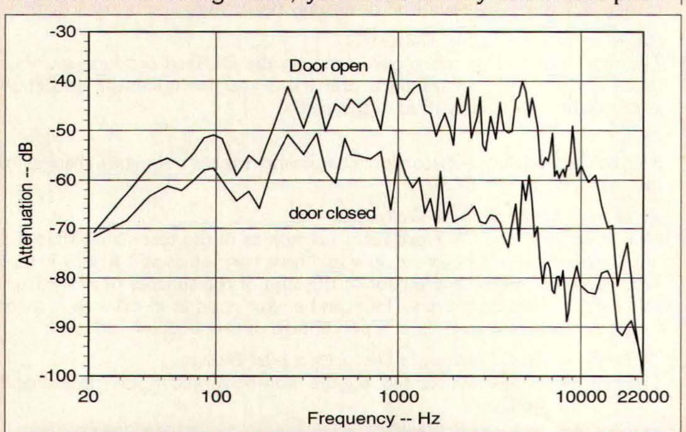


Figure 6. Sound attenuation with open and closed interior door. *Audio Tester* with pink noise. Note that this hollow core door loss is maximum from about 1 kHz to 10 kHz.

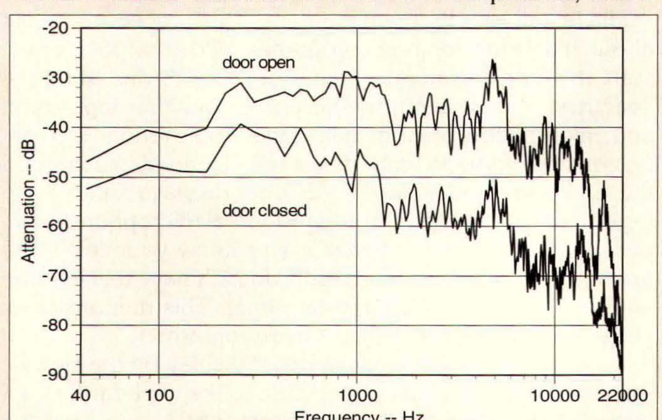


Figure 7. Open and closed interior door response using *Wave Tools* Signal Gen and Spectrum Analyzer. As expected, this graph is very similar to Figure 6.

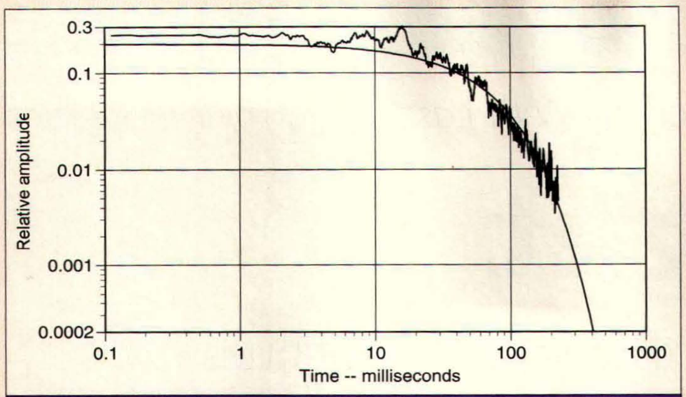


Figure 8. Measured RT60 using SpectraPlus, wav2asc.exe, rt60prep.exe, and DeltaGraph Pro with exponential curve fitting. Room acoustic measurements can be made quicker and more accurately with Sample Champion Pro. (An amplitude change of 1000 is equal to 60 dB.)

is only a little bit of sound out of the speakers. Then the Room Acoustics plug-in makes the measurement by reverse time integrating the impulse response, a method first introduced by M.R. Schroeder [9]. SCP gave me an RT60 of 330 mS, which is very consistent with the 410 mS, considering the amount of data manipulation I had to do to get any number at all.

Rooms with the same RT60 can sound very different, so RT60 isn't the whole story. Sample Champion Pro Room Acoustics plug-in also measures D50 (Definition), which is the ratio of early-arriving to total sound energy and C50 (Clarity), which is the ratio of early-arriving to late-arriving sound energy. These are automatically computer along with RT60 and can be displayed for the whole audio bandwidth or for octave or third-octave bands. In his Case Study #2: Critical Listening Room — Home Theater [10], Sam Berkow says that RT60 "has little correlation with subjective preference." What all this means is, you take all the measurements you can to help point you in the right direction, but then you have to make the room sound good to you (or to your client)!

There is also an argument that a small room doesn't have an RT60 [11]. This may be true if the room is too small to sustain a dense field of decaying reflections. But making these measurements is not an academic exercise — we do it to get some help in making the room sound better: where to use some acoustical tile or change the carpet,

Recording Studio	0.5 second
Broadcasting Studio	0.5
Lecture Hall	1
Movie Theater	1
Home Listening Room	1
Multi-purpose Auditorium	1.5
Opera Hall	1.5
Symphony Orchestra Hall	2
Pipe Organ	3

TABLE 2
Optimum reverberation times (500-1,000 Hz). For music performance, time should be longer at lower frequencies.

or maybe use some wall hangings. So, whether a room has a true RT60 is beside the point if our measurements are useful. There are many texts on architectural acoustics; two that I like are listed in Resources 12 and 13.

There are several really neat, but somewhat pricy software programs that are specifically for sound control in buildings, that is, architectural acoustics. But I'm not going to get into that here, as it's off the topic of general audio testing. That would have to be the subject of another article.

TrueRTA, Version 2.0.1

I didn't use TrueRTA [14] in any of my measurements because it wasn't available when I was making them. But I have since learned that it's a very useful program. It has a sinewave generator covering 5 Hz to 22 kHz, as well as pink and white noise. It also has a digital level meter, a crest factor meter, and a dual trace 'scope. It performs spectral analysis in octave, third-octave, sixth-octave, 1/12-octave, and 1/24-octave bands. The version with the octave-band analysis only is free. And there are three other levels with increased performance at increased price. Level-4 with all the features is $99.95, and (I think) well worth it. Upgrades are free for existing customers.

Some Final Words

The User Guides and printed help files occupy hundreds of total pages for these programs, so I have only scratched the surface in covering their many features. However, I think I've made a good case for using a computer with a sound card and software for most, if not all of your sound testing needs. And with a good sound card the accuracy can be as good as you could get from some pretty high-priced lab instruments. Be sure to check out three more general sound-related web sites listed in Resources 15, 16, and 17. **NV**

RESOURCES

1. Sound card evaluations by Arnold B. Krueger can be found at: www.pcavtech/soundcards/compare/index.htm.

2. DSP Development Corp., 1 Kendall Sq., Cambridge, MA 02139. 617-577-1133, www.dadisp.com.

3. MathSoft, Inc., 101 Main St., Cambridge, MA 02142. 800-628-4223, www.mathsoft.com.

4. Audiomatica. Available from Orca Designs, 1531 Lookout Dr., Agoura, CA. 818-707-1629. www.orcadesigns.com. Clio Lite is available from Old Colony Sound Labs, www.audioxpress.com.

5. SYSid Labs, 1563 Solano Ave, # 211, Berkeley, CA 94707. 510-559-9075, www.sysid-labs.com.

6. MS-DOS program written by the author. You can download it from the *N&V* web site or from www.zianet.com/tdl/magarts.htm. "C" source code is included in the audiotst.zip file.

7. "New Life for a Vintage Audio Filter," *Nuts & Volts*, July 1999.

8. You can find this program along with the new program rt60prep and thd in audiotst.zip. All are MS-DOS programs written in "C" and source code is included.

9. "New Method of Measuring Reverberation Time," *Journal of the Acoustical Society of America*, 1965.

10. Case Study #2, SIA Software Company, Inc., 1 Main St., Whitinsville, MA 01588, www.siasoft.com.

11. TechTalk: "SMAART and Reverberation Time," *Live Sound International*, Feb. 2003, p.86. (www.livesoundint.com).

12. Leland K. Irvine and Roy L. Richards, *Acoustics and Noise Control Handbook for Architects and Builders*, Krieger Publishing Co., Malabar, FL. 1998.

13. F. Alton Everest, *The Masters Handbook of Acoustics, 2nd Edition*, TAB Books, Inc., Blue Ridge Summit, PA. 1989.

14. TrueRTA, True Audio, 387 Duncan Lane, Andersonville, TN, www.trueaudio.com.

15. **www.tracertek.com** sells quality sound cards in the less-than-$100.00 to $200.00 price range. They also sell some interesting and useful audio software.

16. www.tune-town.com is the Car Stereo-Parts Store site. Click on downloads and find a variety of interesting audio related software.

17. www.hitsquad.com is the Musician's Web Center site. Download hundreds of audio and music programs including trial versions, shareware, and freeware in dozens of categories. Also music charts, books, reviews, and discussions.

Exploring and Experimenting With Lasers and Their Properties

Laser Insight

Construction of the Cr:Ruby laser continues ...

Over the last couple of issues, I have been describing the construction of a laser head designed for a Cr:Ruby laser. All the parts that go into the laser head were described with some pertinent information regarding the choice of materials and manufacturing of those parts. This month, the placement of the optical components on the rail will be discussed, and we'll finish the column by seeing what is required for the water cooling system for the laser. If you decide not to include the water cooling, that is okay, but you must remember that the lifetime expectancy of the lamp and the energy output from the laser will be seriously affected.

As I mentioned before, I will describe the assembly of the rail as if you were using a bench plate from Edmund Scientific. This is not the only method of course, and I gave a couple of options in the first part of this project. The mirror mounts can be held down with screws and hold-down bars, while the laser head is bolted down directly through the head with 1/4"-20 screws.

One of the first things you should decide is what you want the laser to do — for applications where a wide laser pulse is required, such as welding or drilling, the mirror mounts and shutter should be positioned close to the laser head. This will afford maximum coupling between the mirrors and highest gain in the resonator, and result in the highest energy extraction from the rod.

Incidentally, although I am describing a Cr:Ruby laser, much of this description will also apply to a pulsed Nd:YAG laser. In fact, if your application is strictly drilling or welding, the Nd:YAG version may be a better choice. However, for holographic purposes, a high quality visible beam is essential, and a wide separation of mirrors is preferable, along with other components to reduce the spatial and longitudinal modes present in the beam, and to reduce the pulse width, but I'll discuss this further later in the project.

Figure 27-1 shows a couple of optical layouts. The first layout is typical for a wide, high energy pulse, useful for drilling or spot welding. This layout can also be used for Nd:YAG. The set-up will give maximum gain in the resonator, but will also give a very divergent beam. Since the focused spot size is dependent on the divergence of the laser beam, there will be some imposed limits on how small a drilled hole or welded spot will be, so you'll have to experiment with lenses and mirror separation to get the desired results.

The second layout is one that I have used many times for producing short, high energy pulses in the multi-megawatt regime. When suitably pumped, this layout can produce a 20-40 nSec pulse at up to 10J output energy (that's over 300Mwatts peak power, folks!). This layout includes a Pockels cell and a Brewster polarizer. Such EO (electro-optical) Q-switched lasers are used quite extensively in cosmetic surgery for tattoo and hair removal, and birthmark removal. Special EO drivers are used in holography to generate two laser pulses (from a few microseconds to about one millisecond apart) from a single lamp flash, and I'll be describing this item in more detail later.

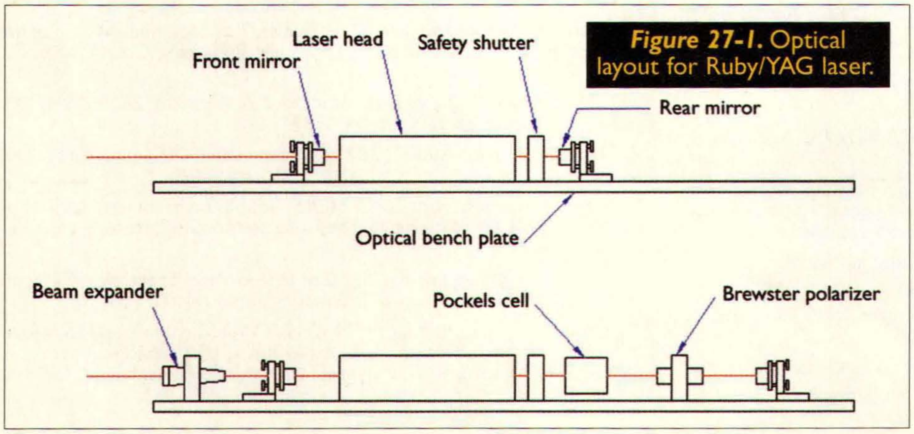


Figure 27-1. Optical layout for Ruby/YAG laser.

Some interesting properties of Cr:Ruby

Two things I should mention about the Cr:Ruby rod are the self-polarization effects (birefringence) and self-absorption (to the radiation) of the crystal. I briefly covered the birefringence effects in an earlier column, but I'll repeat some of that discussion now in case you missed it.

Cr:Ruby has a peculiar property called birefringence that seemingly splits up the electric and magnetic fields in a light beam and sends them along different axes of the rod. Figure 27-2 illustrates this effect.

If a HeNe beam (which is close in wavelength to Cr:Ruby) is projected down the centerline of a Ruby rod, the emerging beam will be seen to have split into two. The two emerging beams are polarized along orthogonal axes, and if a sheet of polarizer film is placed at the output end of the rod and rotated, the separation of the two beams is easily seen.

Similarly, if the polarizer film is placed at the input end of the rod and rotated, the same effects will be seen. The two axes are known in laser circles as the "fast" and "slow" axes, and refer to the direction of propagation of the beam through the rod. The polarization axis of the rod is important in some applications, such as holography, and I will be discussing this more later on in the project.

Cr:Ruby also absorbs its own laser wavelength. When the flashlamp flashes, it emits a broad spectrum of wavelengths from the infrared to the ultraviolet. The so-called "pump bands" of this crystal (those wavelengths that "charge," the rod if you like) contain radiation that includes the lasing wavelength of Cr:Ruby. Because this property results in some of the laser radiation being re-absorbed by the rod, it makes the laser less efficient than other pulsed laser types, and puts the lasing threshold well above that of Nd:YAG.

In other words, because the crystal tends to absorb some of the radiation it produces, it is inefficient, and requires a much stronger pump source than an Nd:YAG laser of the same energy output. For instance, a small pulsed laser I used to work on years ago used a 3/8-inch diameter by three-inch Cr:Ruby rod. The energy input to the flashlamp was 580 Joules at 2.2 kvolts when the laser first started to produce a beam, and was stored in a 240 µF capacitor rated at 5kvolts. The 1/4-inch diameter rod we're using in this laser won't require quite as much energy as this, but it will still be very high. Enough to do serious damage anyway, and the reason for the warnings at the beginning of the previous two columns.

Cooling the laser

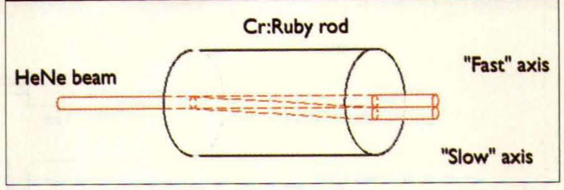
Okay, now we have to talk about cooling the lamp and rod. This is something you may decide to leave out, as I've mentioned before, but there are going to be limitations on what you can do with the laser without cooling.

On the plus side, the laser is easier and cheaper to make, is very portable, and can be made much smaller. On the down side, however, you cannot deliver high energy pulses at a fast rate, and must settle for a pulse every couple of minutes or so, maximum. I recommend cooling with de-ionized water as in most commercial lasers, and that is the basis of the rest of this article.

The water system

Refer to the schematic of the water system shown in Figure 27-3, and note some of the features:

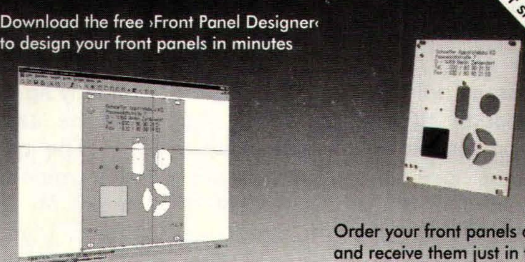
Figure 27-2. Birefringence in a Cr:Ruby rod.



There are many interlocks and monitoring devices built into the cooling system to shut down the power supply if the water temperature exceeds a safe limit, or if the water flow is restricted or stops for any reason.

The water tank holds about one to two gallons of distilled water, which is constantly freed of ion build-up by the de-ionizing filter. The water pump delivers cool DI water to the laser head at about one-half to one gallon/minute. Flow rate is not as important in this laser since the duty cycle is low compared to a CW laser. There is ample cooling-off time between pulses, so that we can be pretty flexible in terms of water delivery.

Looking at Figure 27-3, you'll see the water tank has a connection from low down on the tank to the input port of the pump. This makes the water flow self-starting, and eliminates the need to prime the pump before starting it. It also eliminates problems later on with air bubbles getting into the system, or a loss of prime on the pump. The pump outlet forces water directly to the laser head, where the water flows across both the lamp and the rod. The direction of water flow in the head is not important, since the head design is such



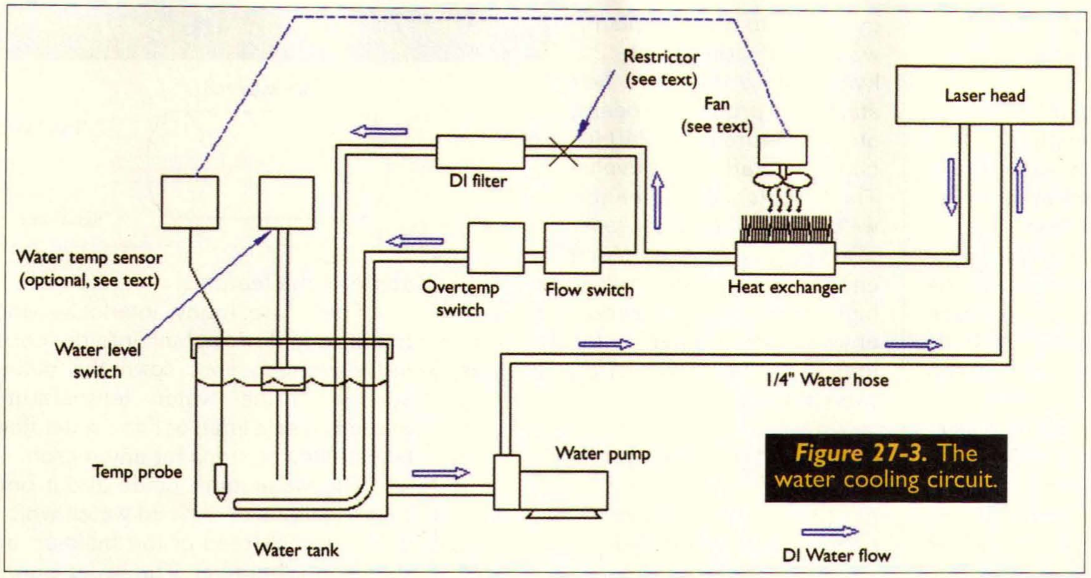


Figure 27-3. The water cooling circuit.

that the flow is across the lamp and the rod in parallel.

After the water leaves the laser head, it travels through the heat exchanger, where the heat from the lamp and rod is given up to forced airflow over the fins surrounding the heat exchanger. Usually, heat exchangers for industrial lasers are of a water-to-water variety, rather than water-to-air, as in this design. The water-to-water type is far more efficient at removing the heat build-up, but is also more expensive, and requires a supply of city water. With the low duty cycle of this laser, water-to-air is a more economical choice.

When the water leaves the heat exchanger, it is teed and follows two paths. The main flow of water, about 90 percent of it, flows through the flow switch and the over-temperature switch back into the water tank. The remaining 10 percent is sent through the DI (De-Ionizing) filter via a restrictor. The restrictor limits the flow rate through the DI filter and, at the same time, limits the pressure build-up in that device.

In this case, the restrictor can be a short piece of stainless steel rod with a small hole (1/8-inch in diameter) through the center of it. The restrictor can be held in place by a screw-type hose clamp. It is only necessary to filter about 10 percent of the water at any time, to keep the water clean. The output of the filter then returns to the water tank.

The flow switch is sensitive to the rate of flow of water through it, and will change state if the flow falls below a certain fixed level. For best service, the lamp and rod have to be kept at a stable temperature (at least within reasonable limits) and a slow-down in water delivery will allow the temperature to rise.

If the flow is dramatically reduced or stops, the flow switch will prevent damage by shutting down the high voltage supply and shutting off power to the pump. If the slow-down is less dramatic, heat may build up faster than the heat exchanger can remove it. In this case, the over temperature switch will shut off the high voltage supply if the temperature of the water exceeds a safe limit.

In the water tank, there are two more sensors: a level sensor for monitoring the level of water in the tank, and a temperature sensor for monitoring the water temperature in the tank. The water level sensor is fairly obvious in its function, and merely provides an indication that the level of DI water is below a certain limit, and should be topped up with fresh water. There is no interaction with the power supply for this sensor — it merely lights an indicator lamp to signal the status of the water level.

The type of switch you get will determine how it gets mounted in the tank. My preference is a floating magnet-type switch that rides on a vertical guide. This type is mounted to the top of the tank, and eliminates any leakage problems associated with any side-mounted switch. But this is only my preference.

The temperature switch is interactive with the heat exchanger, and turns on the cooling fan to direct a stream of air across the cooling fins as the water in the tank heats up. As another alternative, we can let the fan blow continuously across the heat exchanger fins, and not bother with the fan cycling. We'll go more into the details of this and the other sensors as we start to discuss the controls and safety interlocks.

You'll notice that I have drawn the water return hoses as going back into the bottom of the water tank. There is a reason for this. The turbulence that normally occurs when water flow starts tends to stir up ripples in the surface of the water, causing splashing. By placing the hose returns close to the bottom of the tank, the splashing is reduced, and the tendency for air to be entrained into the input of the pump is reduced. If the hoses are coiled as indicated, then the water will be well mixed to a uniform temperature.

Notes on some of the components

I must emphasize the use of plastic or stainless steel components throughout the water system. Copper, brass, aluminum, and iron fittings will decay over time, releasing particles into the water. These particles contaminate the water, and may leave deposits in the pump chamber, on the rod and lamp, etc., causing a loss in output.

Dissimilar metals in contact will release ions into the water through electrolytic action and will make the lamp difficult to ignite, and may cause current to be conducted through the water instead of through the lamp. This is a dangerous situation, and may put the laser rail at a high potential relative to grounded objects. So stay away from these materials — use stainless steel or plastic only!

The hose you use can be fairly small, and 1/4-inch ID refrigerator hose should carry enough water for our purposes. The water pump can also be quite small, and a small or medium size aquarium pump should be adequate. Since the duty cycle on this laser is quite low, there is no need for a high pressure or high flow rate, as long as the water keeps moving. The flow switch should normally be open, and closed when water is flowing through it. The trip point of some switches can be adjusted, but a fixed flow rate switch is okay, too. Try to find one that operates at about one-half gallon/minute. You should be able to get one of these through your local aquarium supply house. The water temperature switch is used to turn on the cooling fan for the heat exchanger, and is a solid-state device. This is also available at aquarium supply houses.

As an alternative, the fan could be left running all the time, eliminating the need for the temperature sensor. This would reduce the cost a little, as well as reduce the complexity. The water level switch is used as an indicator of water level in the tank, and simply causes an LED to illuminate on the front panel when the level drops below a certain minimum. Water loss is inevitable due to evaporation, and so this indicator should be included. The over-temperature switch is wired in series with the power supply drop-out relay, and causes the power supply to drop out if the water temperature gets too hot. The switch should normally be closed, opening at about 100°F. These switches are usually available at appliance repair outlets.

The DI filter is a special filter designed to remove any ion imbalance in the water. One source for this item is Ametek, and they can be found on the Internet at **www.iprocessmart.com/Filters/ametek_cartridges_deionizing.htm.**

The smallest unit they have is their PN PCF1-10MB, with a maximum flow rate of about 0.25GPM, priced at about $26.00, and you can order this item online. There are other sources, of course, and you may want to shop around. The heat exchanger and fan are available from many sources, and consist basically of a closed tube or box with radiant fins mounted to it. The fins help dissipate the heat, and the fan blowing across the fins accelerates the heat flow. It is only necessary to maintain a good airflow across these heat exchangers for them to do their job. Look from heat exchangers on the Internet from a number of suppliers.

Finally, there's the water tank. This can be any size or shape you can conveniently fit into the power supply frame you make or buy, and preferably comes with a lid or cover to prevent any foreign objects from dropping into it. We'll discuss parts placement in the next issue. It should be able to hold at least one or two gallons of DI water in order to form a reasonable "reservoir" at a fairly steady temperature. I didn't have room to go into the water control electronics in this issue, so we'll cover it next time.

FYI: I recently had contact with a web-based machine shop which can supply some of the parts required for this project.

Unfortunately, I got the information too late to include in the July issue, so I will include it here. The address is **www.emachineshop.com/**, and the person to contact is Jim Lewis at 666 Godwin Ave., Midland Park, NJ 07432; Tel: 201-447-9120.

If you have questions about this column, or ideas for future columns, you may contact me as always at **stanley.york@att.net**, or through this magazine. I look forward to hearing your ideas and comments. **NV**

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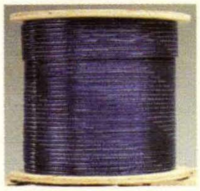

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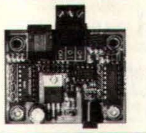

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Continued from Page 59

Dear Nuts & Volts:

It seems that almost every month someone is taking TJ Byers to task for one of his answers. In the interest of accuracy, I'd like to correct some information given on page 94 of the June issue. When asked the difference between YPbPr and YCbCr video formats, TJ states that the P refers to Progressive (scanning?) which has *nothing* to do with the question.

Both Pb and Cb represent the B-Y (blue minus Y) component of a video signal; Pr and Cr carry the R-Y (red minus Y) information.

Although in many cases they are incorrectly used interchangeably, as the questioner points out, Pb and Pr are analog signals while Cb and Cr refer to the digitized versions per the ITU-R BT.601 digital video standard. I'm not sure the P actually stands for anything, any more than the U or V signals (i.e., YUV) from which Pb and Pr are derived. Or, for that matter, why Y was chosen to represent luminance.

Jeff Mazur
via Internet

Dear Nuts & Volts:

The Micro Memories column has been fun. However, whatever happened to Ohio Scientific? They had the back cover advertisement for *Byte* magazine. I recently found one of their computers in the back recesses of my garage.

Maurice Koroniak
via Internet

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Test Equipment

by Jon Williams

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

Stamp Applications

Get Your Motor Runnin'

Most people don't realize that the BASIC Stamp II has actually been around for quite a long time. Like the BASIC Stamp I, it was designed to be a general-purpose embedded controller. And it's a darn good one — just look how many copy-cat products exist today.

Not long after the introduction of the first BASIC Stamp, a new industry was created — the serial accessory industry. It all started with Scott Edwards' "Stamp Stretcher." After that, Scott created the serial LCD controller that we all take for granted (and has been copied by many) and a serial servo controller, as well. With Scott's success, others jumped into the fray, and how there is a multitude of serial accessories that will work with the BASIC Stamp and other micros.

Even Parallax has created serial accessories for the BASIC Stamp — usually in the form of the "AppMod" that plugs into the expansion socket on the (BOE). There's an LED terminal, a sound module, and a compass (like I pointed out earlier). There's a tremendous variety of accessories for the BASIC Stamp.

PWM Made Painless

The latest from Parallax is the PWMPAL. It works very much like an AppMod (programmed through a serial connection and uses the AppMod protocol), but it is physically and mechanically different — it's configured as a "smart socket" (Figure 1). This has been done by other companies and the guys at Parallax like the idea: pop the Stamp out of its socket, drop in the PWMPAL, plug the Stamp into it, and away you go. By mounting the PWMPAL right under the Stamp so that they share pins, the Stamp is given new features. Neato.

So, you're wondering, "What is a PWMPAL, anyway?" Let me tell you. The PWMPAL is a four-channel PWM generator/controller and background counter. Any of the shared PWM pins [P12-P15] that aren't used as PWM outputs can be used by the BASIC Stamp for any purpose. The control and counter pins [P8-P11] can be used as inputs by the BASIC Stamp, even when they're being used for PWM control or counter inputs. They can also be used by the BASIC Stamp as outputs to control a preset PWM channel that is running under hardware control. More on this later.

Like the BASIC Stamp, the PWMPAL is a general-purpose device. Instead of being dedicated to a single function (i.e., servo control or DC motor control), the PWMPAL lets the programmer/engineer specify the "shape" of the PWM output. With this flexibility comes a bit of responsibility, but it's not difficult to do and the benefits of a little effort are

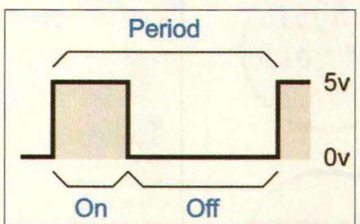


Figure 2

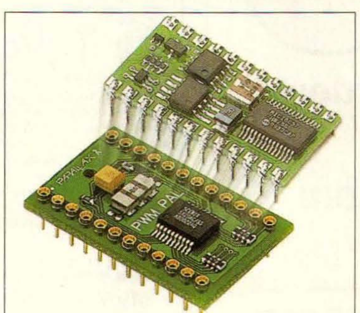
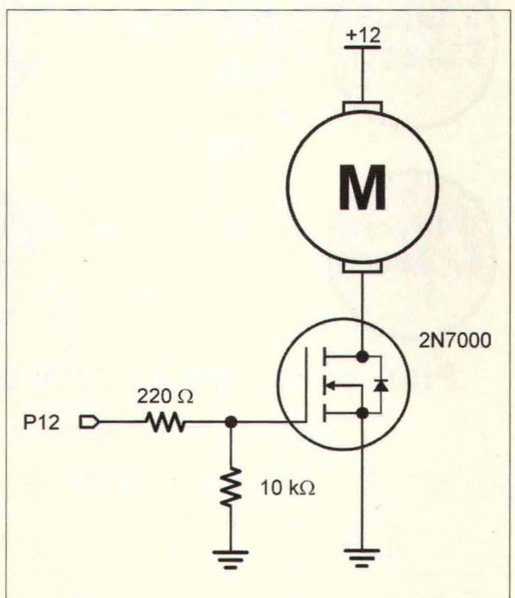


Figure 1



DC Motor Control

certainly worth it.

Making Waves

Before we get to programming the PWMPAL, let's review a couple of small points about PWM waveforms: period, frequency, and duty-cycle.

Figure 2 shows the aspects of standard PWM output waveform. In the PWM cycle, the output will be on for some amount of time, then off for some amount of time. (Note that this is different than the Stamp's PWM function which is designed to create an analog voltage through an RC filter.) The total time for the waveform — on-time plus off-time — is the period. If we divide the period into one, we'll get the frequency (in Hertz) of the waveform. Finally, the duty-cycle of the wave is the ratio of on-time to period.

Here are the essential formulas (and their derivatives) that we'll work with when programming the PWMPAL:

```
Period (s) = On-Time + Off-Time
Frequency (Hz) = 1 / Period
Duty Cycle (%) = On-Time / Period * 100
```

So how do we control these things with the PWMPAL? Each PWMPAL channel has two, 16-bit timers; one for the on-time, another for the off-time. For each count in these timers, we get 25 microseconds. Knowing this, we can calculate the proper values for a waveform we wish to create.

Let's say, for example, we want to control a servo and start with it centered. Knowing what we know about servos, we need the on-time to be 1.5 milliseconds and the off-time to be 20 milliseconds. The rest is simple math: 1.5 milliseconds divided by 0.025 milliseconds (25 microseconds) is 60. This will be our on-time count. Next we take 20 milliseconds and divide by 0.025 milliseconds to get 800.

The next step is to send these counts to the PWMPAL. Part of the PWMPAL design is the fixed serial connection that is on P0 of the BASIC Stamp. You'll have to keep this in mind when you're designing the PWMPAL into your projects. What we're going to do, then, is send the counts using the PWMPAL's version of the Parallax AppMod protocol. The serial data string always starts with "!," is followed by the device identifier "PWM," then the command. The command for sending "motor" counts is going to be "M," followed by the motor number.

The PWMPAL's outputs correspond to Stamp pins P12 (M1) through P15 (M4). If we want to connect the servo to P15, here's the command to send the centering counts:

```
SEROUT 0, 6, ["!PWMM4", 60, 0, 32, 3]
```

Huh? Why four bytes when we just have two counters?

Remember, the counters are 16 bits wide and SEROUT works with bytes. Normally, what we're going to do is use Word variables for the counters and get some help with LOWBYTE/HIGHBYTE or BYTE0/BYTE1 modifiers. And before I forget, I need to mention that the PWMPAL will automatically detect baud rates of 9600, 19.2K and 38.4K.

Since we're a learn-by-doing crowd, let's actually hook it up and make it do something — our example will use fairly simple parts and demonstrate nearly all the capabilities of the PWMPAL.

After playing with this demo, you should be able to make the PWMPAL work for you in just about any application. What I've done is taken the separate projects from the PWMPAL docs (yes, I wrote them) and created a super project. The idea is to show you the possibilities and let your imagination run wild from there.

The circuits for this demo are pretty easy: an active-high push-button input, a buffer circuit (MOSFET) for a small DC motor, and a bi-color (red-green) LED. We'll demonstrate the PWMPAL by setting P8 as a control channel for the motor. When the switch is pressed, the motor will run — this is all under control of the PWMPAL and does not burden the BASIC Stamp. Since P8 is an input, the BASIC Stamp program can monitor it, and we'll do that to ramp the motor speed.

Finally, we'll demonstrate the phase control of the PWMPAL that will let us send an AC waveform to the LED, making it appear yellow by switching quickly between red and green. This all sounds like quite a lot, but as you'll see, it's very easy to do.

Rev It Up

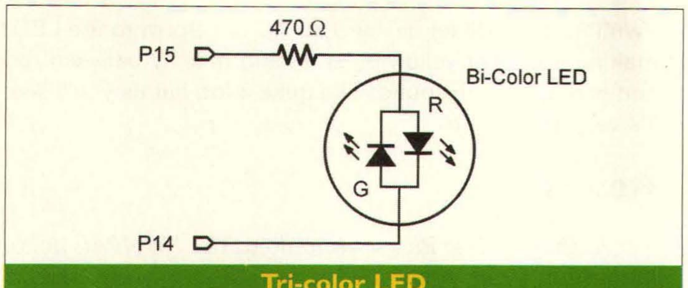
Author's Note: Please download the PWMPAL documentation (from the Parallax web site) for reference to the various commands as we work our way through this example.

This program requires a bit of set-up before we get to the heart of it. The purpose of this set-up section is to enable a counter channel on P8, clear that counter, then enable the motor output on P12 and set P8 as its control input. As you can see, P8 serves two purposes: it controls the operation of the motor and, it serves as a counter. What we'll be able to do, then, is to count the number of times we run the motor.

Here's the code:

```
Setup:
  SEROUT PpPin, PpBaud, ["!PWMSP", %00000001]
  SEROUT PpPin, PpBaud, ["!PWMX1"]
  SEROUT PpPin, PpBaud, ["!PWMSS", %00010001]
```

The first line enables the counter on channel 1 (P8).



Tri-color LED

Later, we'll resend the phase/counter byte to enable the LEDs — for the moment we want them off.

Next we'll make sure that the counter is clear by sending the "X1" command and, finally, we'll enable the motor under hardware control by setting the appropriate bits in the status/control byte. Note that any disabled "motor" outputs float, so these pins can be used by the BASIC Stamp for other functions.

Since the main loop of the program is fairly large, we're going to break it up into logical sections. The first section monitors the button input and adjusts the motor speed while the button is being pressed.

Remember, the PWMPAL actually activates the motor when this input is high. We're using the BASIC Stamp to update the motor's speed.


```
Main:
  DO
    IF (RunMotor = Yes) THEN
      IF (mSpeed < 100) THEN
        mSpeed = mSpeed + 1 MIN MinSpeed
        GOSUB Set_Motor_Speed
        update = Yes
      ENDIF
    ELSEIF (mSpeed > 0) THEN
      mSpeed = 0
      update = Yes
    ENDIF
```

As you can see, this first section is pretty straightforward. We monitor the switch input and, when pressed, we compare the current speed value to 100. If the speed is less than 100, we'll increment the speed and send the new value to the motor.

We'll also set the variable update so that the screen will reflect the new speed. Updating the motor speed is a fairly simple matter of using the speed value as the on-time count and subtracting this count from 100 for the off-time.

```
Set_Motor_Speed:
  IF (mSpeed < 100) THEN
    tOn = mSpeed                    ' set duty cycle
    tOff = 100 - mSpeed
  ELSE
    tOn = $FFFF                     ' full on for 100%
    tOff = $0001
  ENDIF

  SEROUT PpPin, PpBaud, ["!PWMM1",
                          tOn.BYTE0, tOn.BYTE1,
                          tOff.BYTE0, tOff.BYTE1]
  RETURN
```

The exception, of course, is for 100 percent, as we cannot have a zero off-time. What we'll do is "cheat" a bit and set the on-time value to the maximum ($FFFF) and the off-time to the minimum ($0001). What we actually end up with is a duty cycle of 99.9985 percent — that should be close enough to 100 percent to run the motor at full speed.

Now, if the button isn't pressed and the current speed is greater than zero (as when the button is first released), we'll set the mSpeed value to zero and set the update variable.

Notice that we don't have to send the zero speed to the PWMPAL. The reason is that we've enabled hardware control of the motor, so it will stop as soon as we release the button.

The next section of the main loop retrieves the counter channel from the PWMPAL. Like PWM control, counting happens without intervention of the Stamp — we simply need to retrieve the count when required.

```
SEROUT PpPin, PpBaud, ["!PWMC1"]
SERIN PpPin, PpBaud, [runCount.BYTE0, runCount.BYTE1]
```

The first thing we have to do is tell the PWMPAL to send a counter value back to the BASIC Stamp. Immediately following this command, we'll use SERIN to capture the counter value — low byte, then high byte.

The final section will handle the update variable and serves two purposes: it will display the current motor speed and cycle count, and it will update the LED modulation based on the current motor speed.

```
  IF (update) THEN
    DEBUG HOME,
          "Speed.... ", DEC mSpeed, CLREOL, CR,
          "Cycles... ", DEC runCount, CLREOL

  LOOKDOWN mSpeed, <=[24, 80, 95, 100], ledState
  IF (ledState <> lastLed) THEN
   ON ledState GOSUB Led_Off, Led_Green, Led_Yellow, Led_Red
      lastLed = ledState
    ENDIF
    update = No
  ENDIF
  PAUSE 100
LOOP
```

The DEBUG section needs no explanation. I will remind you, however, that with PBASIC 2.5 you can spread comma-delimited lists across multiple lines. This is an especially good idea when using DEBUG, SEROUT, and SERIN as these functions are [internally] complicated and take a lot of code space. By using one DEBUG statement instead of three, we save EEPROM space that may come in handy later.

The final section of the main loop updates the LED. I like LEDs and I am particularly fond of bi-color LEDs because they can be so useful. By connecting the PWM-PAL, we can actually get three colors out of a two-color LED. How does that happen?

The bi-color LED is actually a red LED and green LED that are connected back-to-back in the same package. When current flows one direction through the leads, the red LED will light. When the current is reversed, the green will light. If we can manage to switch the two back-and-forth very rapidly, our eyes will mix the colors and we'll perceive yellow. It's a cool trick.

One of the unique features of the PWMPAL comes into play to make this happen — the ability to set the phase of the outputs. What this is actually doing is allowing us to tell the PWMPAL to start on its high phase or its low phase. With careful programming, we can set two pins to run at opposite phase and the same frequency and duty cycle to create a TTL AC waveform. I'm going to use it to modulate the LED, but my buddy Chuck (who created the PWMPAL) has used this ability with suitable buffering to provide AC to a specialized sensor.

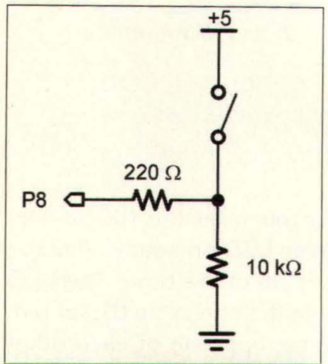
Back to the code. A LOOKDOWN table uses the current motor speed to set the value of ledState. If ledState has changed since the last loop through, we'll call the appropriate update routine. The first is simple — it extinguishes the LED by disabling both its PWM outputs.

```
Led_Off:
  SEROUT PpPin, PpBaud, ["!PWMSS", %00010001]
  RETURN
```

The next routine works very much like the 100 percent motor update by setting the green LED on nearly all of the time and the red LED off nearly all of the time. The LED will look green — you'll never see the one cycle blip of red. Notice that the phase bits are set opposite of each other with the M3 output starting on its high cycle. The red LED control code is identical; the counter values and phase controls are simply reversed.

```
Led_Green:
  SEROUT PpPin, PpBaud, ["!PWMM3", $FF, $FF, $01, $00]
  SEROUT PpPin, PpBaud, ["!PWMM4", $01, $00, $FF, $FF]
  SEROUT PpPin, PpBaud, ["!PWMSP", %01000001]
  SEROUT PpPin, PpBaud, ["!PWMSS", %11010001]
  RETURN
```

Making the LED look yellow is not tough, but just a tad trickier than you might think at first. When I first wrote this program, I set the duty cycle to 50 percent — it didn't look yellow at all, in fact, it looked down-right red. The reason is



Switch Input

Resources
Jon Williams
jwilliams@parallax.com
Parallax, Inc.
www.parallax.com

out to be about 18 percent.

that red and green LEDs are made from different materials and given the same current, the red LED will light a bit brighter. I experimented until I found a satisfactory duty cycle that caused the LED to look yellow. It turned out to be about 18 percent.

```
Led_Yellow:
  SEROUT PpPin, PpBaud, ["!PWMM3", $12, $00, $04, $00]
  SEROUT PpPin, PpBaud, ["!PWMM4", $04, $00, $12, $00]
  SEROUT PpPin, PpBaud, ["!PWMSP", %01000001]
  SEROUT PpPin, PpBaud, ["!PWMSS", %11010001]
  RETURN
```

Time To Get My Robots Runnin'

Well, that's about it. As you've just seen, the PWMPAL is pretty easy to deal with and, at the same time, offers up quite a bit of flexibility. Keep your eyes on the Parallax web site for application notes — like every new product, people will find interesting things to do with it over time and we'll certainly make that information available to everyone.

Finally, some of you may wonder why I did such a simple interface to the motor, and didn't go into H-Bridges and all that kind of circuitry. I didn't because my old pal Scott Edwards already did — back in the Jan. '97 issue. Don't have it? No problem, you can order reprints of this column in *The Nuts & Volts of BASIC Stamps* book series from *Nuts & Volts* or Parallax. And if you really don't want to have a book handy (which would be silly, of course), you can still download electronic reprints of the column from the Parallax web site.

Have fun with the PWMPAL — I've got a couple robots to update with it and I'd better get started. One of them uses a Sony PlayStation controller as a leash. If you liked Aaron Dahlen's neat article on PSX controller interfacing in June, then be sure to tune in next month as I will be showing you some "inside tricks" that will help you get the most out of it.

Until then, Happy Stamping! **NV**

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Robotics Resources

Using Toy Parts for Building Robots

Toys can be a cheap source of useful components, from wheels and gears to motors and "blinky lights." Most toys are mass produced, so they're relatively cheap for what you get. And since the popularity of toys tend to run in cycles, you can often find great deals on discontinued items. Though there are literally hundreds of types of toys, three stand out as ideal for constructing inexpensive robots: construction toys, ready-made toys that can be disassembled for their parts, and so-called "dollar store" toys, which are a good source for basic parts.

Construction Toys

Construction toys come as a box of parts. Most are snap-together.

LEGO®

LEGO has become the premier construction toy, for both children and adults. The LEGO Company, parent company of the LEGO brand, has expanded the line to educational resources, making the ubiquitous LEGO "bricks" common around the world. LEGO also makes the Mindstorms, a series of sophisticated computerized robots. The LEGO Technic line of LEGO sets provides additional parts for robot construction. The pieces are engineered to fit the "classic" LEGO bricks, but add useful beams, connectors, and other parts to provide greater flexibility.

A LEGO Technic beam has holes drilled through its sides for attaching to connector pieces. These holes are perfect for mounting LEGO components onto the rest of your robot.

MEGA BLOKS®

The MEGA BLOKS toys span a variety of play sets, from their Dragon fantasy line to their motorized robots. The MEGA BLOKS toys are competitively priced, and though the company is careful about touting it, the construction pieces are more-or-less "LEGO compatible." (I put this in quotes because while many of the MEGA BLOKS pieces will fit LEGO pieces, interchangeability is not the thrust of the product.)

Certainly, one use of MEGA BLOKS is as a low-cost alternative for some basic LEGO pieces, but for the robot builder, you'll be interested in such products as their Battle Bloks RC, which are radio-controlled motorized platforms that can be readily converted to robotics use. Battle Bloks use a six-wheel "all terrain" design, along with dual motors, that can be used to create a powerful and zippy robot. The Battle Bloks bases are readily-hackable by adding your own control electronics.

If you've played with LEGO for any length of time, especially LEGO Technic, then you know certain construction techniques allow you to create self-locking designs that defy coming apart accidentally. MEGA BLOKS lacks many of the Technic-style pieces, and its parts are basically the core LEGO bricks and plates. If you want a more permanent creation, you may need to glue the pieces together.

Whereas LEGO uses ABS plastic for its pieces, MEGA BLOKS uses polystyrene, the same material found in plastic model kits. For a strong bond, you can use plastic model cement; for a less permanent bond, a flexible silicone-based or silicone-like adhesive, such as Household Goop, can be used.

Fischertechnik

The Fischertechnik kits, made in Germany, are favored in higher-education classes, and even some colleges and universities. More than "toys," Fischertechnik kits offer a snap-together approach to making working electromagnetic, hydraulic, pneumatic, static, and robotic mechanisms. All the Fischertechnik parts are interchangeable, and attach to a common plastic base plate. You can extend the lengths of the base plate to just about any size you want, and the base plate can serve as the foundation for your robot. You can use the motors supplied with the kits, or use your own motors with the parts provided.

K'NeX®

K'NeX uses unusual half-round plastic spokes and connector rods to build everything from bridges to Ferris wheels to robots. You can build a robot with just K'NeX parts, or use the parts in a larger, mixed-component robot. For example, the base of a walking robot may be made from a thin sheet of aluminum, but the legs might be constructed from various K'NeX pieces. A number of K'NeX kits are available, from simple starter sets to rather massive special-purpose collections (many of which are designed to build robots, dinosaurs, or robot-dinosaurs). Several of the kits come with small gear motors so you can motorize your creation. The motors are also available separately.

Erector Set®

Erector Set, now sold by Meccano®, was once made of all metal. Now, they commonly contain both metal and plastic pieces, in various sizes, and are generally designed to build specific vehicles or other projects. Useful components of the kits include pre-punched girders, plastic and metal plates, tires, wheels, shafts, and plastic mounting panels. You can use any as you see fit, assembling your robots with the hardware supplied with the kit, or with 6-32 or 8-32 nuts and screws.

Over the years, the Erector Set brand has gone through many owners. Parts from old Erector Sets may not fit well with new parts, including — but not limited to — differences in the threads used for the nuts and bolts. If you have a very old Erector Set (such as the ones made and sold by Gilbert), you're probably better off keeping it as collector's items, rather than raiding the set for robotic parts. Similarly, today's Meccano sets are only passably compatible with the English-made Meccano sets sold decades ago. Hole spacing and sizes have varied over the years, and "mixing and matching" is not practical, or desirable.

Robotix®

The Robotix kits, originally manufactured by Milton-Bradley and now sold by Learning Curve, are specially designed to make snap-together walking and rolling robots. Various kits are available, and many of them include at least one motor — you can buy additional motors, if you'd like. You control the motors using a central switch pad.

The structural components in the Robotix kits are molded high-impact plastic. You can connect pieces together to form just about anything. You can cement the pieces together to provide a permanent construction.

Capsela

Capsela sells popular snap-together motorized parts kits that use unusual tube and sphere shapes. Capsela kits come in different sizes and have one or more gear motors that can be attached to various components. The kits contain unique parts that other put-together toys don't, such as plastic chains and chain sprockets/gears. Advanced kits come with remote control and computer circuits. All the parts from the various kits are interchangeable. The links of the chain snap apart, so you can make any length chain you want. Combine the links from many kits and you can make an impressive drive system for an experimental lightweight robot.

Inventa

UK-based Valiant Technologies offers the Inventa system, a reasonably-priced construction system aimed at the educational market. Inventa is a good source for gears, tracks, wheels, axles, and many other mechanical parts. Beams used for construction are semi-flexible and can be cut to size. Angles and brackets allow the beams to be connected in a variety of ways. It is not uncommon — and, in fact, it's encouraged — to find Inventa creations intermixed with other building materials, including balsa wood, LEGO pieces, you name it. Inventa products are available from distributors, which are listed on the Valiant web site at **www.valiant-technology.com**.

Zoids

Tomy's line of Zoids are construction toys designed to build a specific mechanical creature. Many are motorized, either with a battery-operated motor, or with a wind-up mechanism. Zoids uses only snap-together assembly.

While each Zoids kit makes a specific design, many of the parts are common to each kit, and you can use them to build your own creation. You can also use the electric or wind-up motors for your own robots.

Scavenging Ready-Made Toys

Ready-made toys are those that come pre-assembled, but that can be taken apart for useful parts. Good examples are Bio-Bugs (Wowwee), Furby (Tiger Electronics), and various motorized Tonka (and similar) tractors and trucks.

These, and other toys like them, can often be found on the clearance aisles, at garage sales, and even in thrift stores. At full price, many of these toys don't have enough useful parts in them to justify their cost, so always strive to purchase them used or at a discount.

Best Traits of Scavenged Toys

Here are the common elements of the ideal ready-made toy for scavenging:

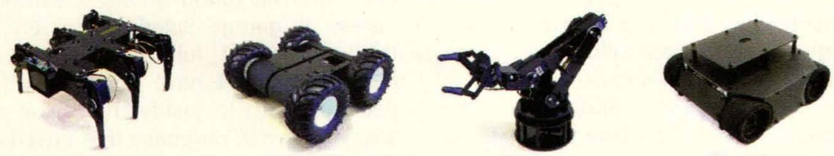
• It is motorized, preferably with an electric motor. This category includes small "4WD" cars and trucks. They contain one motor that drives all four wheels at a time. You can readily adopt two of these toys for use in a traditional two-motor robot design. Just pop off the wheels on one side of the motor, and mount the two motor/wheel assembles onto your robot. Each motor/wheel assembly can be independently operated under electronic control.

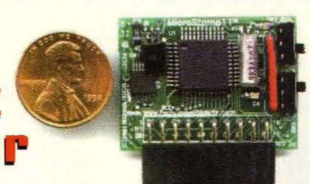
• It uses a self-contained speed-reduction gearbox rather than gears mounted in the chassis of the toy. The latter is actually far more common, and not as useful, because you cannot readily repurpose the gearbox in your own creations. Self-contained gearboxes can be yanked out of the toy and implanted directly into your robots.

• If motorized, it uses electronic control for the motors, rather than mechanical. With some of the Tonka and other tractor-type toys, the motors are controlled by operating levers, which are really mechanical links.

To save costs, these toys use a single motor that is mechanically coupled to various wheels, treads, joints, and other articulations. Most likely you won't be able to adapt these often-elaborate mechanical links into your robot without considerable effort, so it's best to just concentrate on the parts you can readily pull out and reuse.

• It uses screws for assembly. This enables you to disassemble the toy by removing the screws. Toys that are made by gluing, hot-bonding (a kind of "spot welding" for plastic), or hydraulic press-on joints are harder to take apart.





Hacking Motorized Vehicles

While many toys simply beg to be yanked apart for their guts, others are useful in much of their original form as robot bases. Motorized radio control cars and treaded vehicles (e.g., Tonka or New Bright) are among the most common ready-made toys that are used "whole" as a robotic platform. The best such toys use a separate body and chassis — you can remove the body and use just the bare chassis. It's easier to mount your robot parts to the chassis and, of course, your robot looks less like a 1975 Le Mans (dark blue with white racing stripe) or yellow Caterpillar earthmover.

There are literally hundreds of motorized remote control cars and toy threaded vehicles, and not all toys are universally available to everyone, or would be considered inexpensive enough by all to hack. So, if you're interested in using a motorized car or other vehicle as a robot base, know it's a project that is best suited for those who enjoy experimentation and tinkering. Since the toy may be ruined in your hacking efforts (it happens to even the most seasoned robot builder), it's best to use only toys purchased at a discount, either on clearance, at a thrift store or garage sale, or even pulled from your son's closet of "forgotten stuff."

Scavenging "Dollar Store" Toys

A relatively new kind of retail store in North America and elsewhere is the "dollar store," so-named because everything costs a $1.00 or $0.99, or something close to it. More than likely, there's at least one dollar store in your neighborhood, and this store is practically guaranteed to sell a wide assortment of really cheap toys. And I do mean cheap, in both cost and manufacture. These toys are made for pennies, and imported in very high quantities. While they're not well-made toys, some do contain parts that can be used in your robots.

That's the good news. Even better news is that each dollar store (and dollar store chain, like 99 Cents Only) carries its own line of imported goods. So, even if one store doesn't carry what you need, the next one may. However, it also means that the pickin's are sporadic — what I can find at my local dollar stores may be different from what you can find. It's all one big crapshoot. As you scan the wall of toys at the store, be on the lookout for the following:

- **Electric motorized vehicles**. Some are self-running, but others are operated by a wired remote. I've found a significantly high failure rate in these toys, usually from some problem in the remote (which is also an AA battery holder). You may not be able to use the remote, but you can yank apart the toy for its motor, gears (if any), wheels, axle, and other parts.
- **Wind-up motorized vehicles**. You can make your own robotic wind-up toys with the wind-up mechanism for a car or truck. Look for toys with a self-contained winder (most have this). I prefer the mechanisms that are wound by spinning a knob, but there's also pull-back (friction) and pull-string assemblies.
- **Miniature non-motorized vehicles**. Rob them of their wheels, which can be used as small support casters, or as drive wheels for miniature robots.
- **Miniature skateboard or scooter toys**. These also have nice wheels you can use on smaller robots.
- **Big plastic toy vehicles**. These have larger two- to four-inch diameter wheels. The better wheels use a softer rubber, but the hard plastic wheels can also be useful. Be sure the wheels can be pulled off the axle without damage.
- **Friction spark guns, vehicles, and other toys**. For decoration purposes, remove the spark wheel and mount it on your robot for a rad design. You can spin the wheel with a small motor. Remember that sparks are white; if you want colored sparks, mount some colored plastic gels over the wheel.

The vast majority of dollar store toys use screw assembly. You need a set of #0 and #00 (jeweler's) Philips screwdrivers, and possibly a pair of needle-nose pliers and nippy cutters. I regularly save the tiny screws (they're size 0 to 000). They're self-tapping and come in handy for various lightweight fastener jobs — plus they're effectively free.

Occasionally you'll run into toys that use rivet construction, but you may be able to cut apart the plastic to get to the juicy bits inside. On rare occasion, the toy is constructed in a way that defies disassembly. You can use a hacksaw to rip it apart.

Online Sources for Low-cost Toys

Amazon.com
www.amazon.com

Best-known as a book seller, Amazon also sells toys through affiliations with Toys R Us and Imaginarium. The latter specializes in unique educational products.

Construction Toys
www.constructiontoys.com

Robotics Resources

Online and local retailer of construction toys. These toys are available both online and in the retail store: Capsela; Eitech; Erector; Fischertechnik; Geofix; Geomag; K'NeX; LEGO Dacta; Roger's Connection; Rhomblocks; Rokenbok; and Zome System.

Creative Playthings
www.constplay.com

Early childhood construction toys; use them for parts.

e-Hobbyland
e-hobbyland.com

Well-established retail and online seller of all types of toys.

FAO Schwartz
www.fao.com

Though this world-famous company is in receivership (they filed for bankruptcy), they are still in operation, and still offer some of the most unique toys on the planet.

KBtoys.com
www.kbtoys.com / www.etoys.com

Online mail order for KB Toys retailer. Check often for deep discounts on LEGO, K'NeX, and other brands.

LEGO Shop-at-Home
shop.lego.com

Online outlet for LEGO products, including spare parts (when available).

Manley Toy Direct
www.manleytoy.com

This is the direct sales site for Manley Toys, makers of the robotic dogs and other products. Low prices, but minimum orders may apply.

Ohio Art
www.world-of-toys.com

Best known for their Etch-A-Sketch product, the company also sells various children's toys with hack potential. Products available online or at most any retail toy store.

Only Toys
www.onlytoys.com

Only Toys carries metal Erector sets — most are for building vehicles, and some (like the Steam Engine) are quite elaborate. The company also sells Rokenbok radio-controlled toys.

Target
www.target.com

Retail stores and online site. Both offer great deals in clearance items. Make it a habit of regularly checking the web site for clearance items.

Timberdoodle
www.timberdoodle.com

Timberdoodle specializes in home education products. They offer a good selection of Fischertechnik kits at good prices. Also sells Capsela, K'NeX, and electronics learning labs. Be sure to check their "swan gong" closeout deals.

Wal-Mart
www.walmart.com

Retail stores as well as web site, Wal-Mart is arguably the world's largest seller of toys. Be sure to check out their toy clearance items. **NV**

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In The Trenches

An Electromagnetic Interference Primer

EMI (ElectroMagnetic Interference) is never good and, on occasions, it can be devastating. There are two basic concerns. The first is how sensitive your product is to EMI, and the second is how much EMI your product generates. We'll look at ways to help make your product better. In addition, we examine some other concerns.

Standards

First of all, you should know that there are standards for EMI. Probably the most important standards for American products is the FCC (Federal Communications Commission) Part 15. It provides exact EMI limits. About 10 years ago, I bought a hard copy of these standards from the Government Printing Office for $19.00. Currently, these standards are available on the web (ref. 1). The whole of the "Code of Federal Regulations 47 Parts 0 to 19" (CFR 47) is a useful reference.

It's probably important to mention EMI compliance. As I understand the regulations, any commercial electronic product is supposed to meet FCC EMI standards. There are exceptions for some industrial products, instrumentation, and medical devices, as well as for some other items.

But any computer product, any TV or radio product, any product with a crystal over 32KHz, and many other items are supposed to be tested for compliance.

In practice, this doesn't seem to be the case for many small to medium volume products I've seen. From a practical standpoint, unless someone lodges a complaint, it is unusual for the FCC to take an interest in a product. However, they do have the authority to fine the manufacturer and stop production.

Generally, to have your product certified, it has to be tested at a "Certified Testing Laboratory." Yes, this is expensive. You can certainly do many of the tests yourself. However, that requires fairly expensive RF equipment and an isolated space for testing. The specifications for the tests are in the CFR 47. You should also be aware that, in general, the European Community is much more strict with certification. Additionally, their standards are more difficult to meet than the US standards.

EMI Sources

There generally are two causes of most EMI: fast electronic switching and sparking. And there are generally two ways EMI travels: through the air (radiated) or through a wire (conducted).

The most difficult to control is typically sparking. This is because sparking is usually a by-product of a switch. This "switch" can certainly be the brushes in a motor or generator. The spark generates powerful RF (Radio Frequency) noise over a huge spectrum. It can often affect other electronic products hundreds of feet away.

And, since motors (the most common culprit) are basically coils connected directly to the power source, any noise created is immediately coupled into the power source conductors. Switched inductors have a tendency to spark because of high voltages that occur when the power is removed. This is called inductive kickback. The greater the voltage and current, the greater the problem can be.

Fast electronic switching is the other common EMI source. Any oscillator is really a small radio station. Often, circuits have several oscillators (which can cause self-induced EMI). Whenever a digital circuit changes state, the circuit board trace acts like a small transmitting antenna. The fast edges of the signal can often have frequency components of 500 MHz or higher. This means that the small inductance of a trace and parasitic capacitance can create a resonant circuit! When this occurs, nasty things happen.

As you probably noticed, both sources of EMI are the result of a changing voltage. Sparks are rapidly changing voltages as are digital signals. In fact, all conventional EMI sources are the result of changing voltage or current. The faster the change, the greater the EMI. The higher the current, the greater the EMI. This is also known as "delta V over delta T." (Usually shown symbolically as a fraction with a small triangle and a "V" in the numerator with another triangle and a "T" in the denominator.) This relationship is just the amount of change of the voltage ("V" above) over time ("T" above) or, more simply, the rate of change.

And, while the most common sources of EMI have been noted, *anything* that causes a change in voltage or current can be a source of EMI.

Dropping Off or Picking Up

There are two points of view concerning EMI. Is your product picking up interference and malfunctioning? Or, is it sending out too much noise? Different classes of circuits tend to do either one or the other, but usually not both. However, there are exceptions.

For example, analog circuits are usually more likely to suffer from picking up EMI. There are plenty of amplifiers that pick up the local radio station. Digital circuits tend to be emitters. However, the subclass of digital CMOS tends to pick up EMI rather than generate it. This is because of the extremely high input impedance and relatively slow outputs. The early digital clock ICs were notorious for being fast because noise would add clock pulses to the counter chain.

Mixed class products can be troublesome because they may require components that don't work well together. For example, motor control circuits often have sensitive sensors in close physical and electrical proximity with high-power coils. In this case, the initial concern is with self-generated EMI.

Most often, the EMI concern is practical. People don't worry about emitted EMI unless the product has to meet standards. And, they often don't test for susceptibility to EMI. If it works in the laboratory, it must be okay. Besides, all of these tests take time and money. There's no sense to go out looking for trouble, is there? Unfortunately, this is where the problems start.

Horror Stories

We've all heard about the effects of EMI. The stories of how laptop computers affect aircraft instruments. Or, how the hospital security guard's radio caused all the intravenous controllers on the floor to malfunction. Or, about the microwave oven that interfered with a pacemaker. There are too many to list.

The point I'm trying to make is that EMI is an environmental factor. Just like temperature, vibration, and humidity. From the start of the product design, these factors should be addressed.

Failure to do so can lead to products that won't sell as well as they could. (You can be sure that the hospital looked for different radios and better EMI resistant equipment before buying more. Wouldn't you?)

EMI can also be thought of as a type of environmental pollution, like litter, exhaust, chemicals, and noise. Your product has to work in this environment. Conversely, a product that pollutes less is always good for the environment.

Designing Your Product to be Less Susceptible to EMI

I am not going to spend time on design details that can be found in any of the numerous books and articles on the subject. Rather, I want to discuss general factors that can be incorporated in your product from the start of the design.

1) Size matters. The smaller physical size of your product, the better. This is because short wires and traces have less exposure to EMI and are less effective as antennas for EMI. (Smaller size generally reduces the cost, as well.)

2) Lay out the PCB (printed circuit board) by hand. Inexpensive autorouters don't know anything about EMI. They simply go point-to-point. There are some expensive ($30,000.00) RF simulators that can analyze a PCB, but are probably too pricey for most of us. Also, use wide traces and lots of ground plane. The wide traces reduce impedance and the ground plane helps to shield/absorb EMI.

3) Use currents rather than voltages. Or, a similar approach is to use low impedance circuits. EMI is generally high voltage with low current. By sensing current, or forcing the voltage to contain significant current, EMI can be overwhelmed.

For example, I had a client that made overhead electric hoists. There was a 20-foot long cable (unshielded) with switches that hung down for the operator to control. These wires went to a CMOS microprocessor (uP). Naturally, there were huge problems. The fix was to use opto-isolators. The switches turned on LEDs with currents, which EMI couldn't do.

This also means to use low-value resistors in op-amp circuits. Keeping the ratios the same keeps the basic performance the same. However, the signal needs more current to drive the lower impedance. This works well when you have control of the signals. (If you have a signal that is inherently high impedance, a buffer at the start can be helpful.) This approach does require some additional power.

Conversely, use higher value capacitors for lower impedance. Again, keeping the ratios the same has little performance change.

4) Use standard, low-noise techniques. Even if your design isn't low noise, designing for low noise makes your product more EMI resistant.

5) Use a metal enclosure and/or shielding. While plastic is cheaper, metal is much better. There are some metalized plastics or foil/plastic laminates that fall in the middle of cost and performance. A cost/benefit analysis may be useful here.

Designing Your Product to Generate Less EMI

Some of the factors are the same.

1) Keep the design small. Again, smaller radiating surfaces and better grounding reduce emissions.

2) Hand layout the PCB. Wide traces on the PCB reduce impedance.

3) Use a metal or shielded enclosure.

Some of the factors are reversed from above.

4) Use voltage rather than current. This translates to low-power, high-impedance circuits. The reason is that the less power that is used, the less power there is to be radiated. (When was the last time your wristwatch caused a problem?) Using less power often translates into lower costs because of reduced power supply requirements.

Some factors are new.

5) Use the lowest frequency practical. Most uC applications can run at 32,768 Hz (standard watch crystal frequency). Why use a higher frequency crystal that is more expensive when a $0.20 watch crystal will work? What's more, running at 32,768 Hz may allow your product to be exempt from FCC approval. You should always select this as your first choice. A higher frequency should only be used when really necessary.

6) Use "slow" digital ICs. Much of the EMI emissions come from harmonics of the sharp edges of transitions rather than from the rate of transitions. Again, you should choose the slowest, lowest power digital family that fits your application. The 4000 series is very good.

7) Use ASICs (Application Specific Integrated Circuits) or other complex ICs instead of multiple ICs. This is another form of reducing size. ASICs and complex ICs eliminate interconnecting PCB traces that would otherwise be needed. Again, if the radiator is chip-sized, there won't be much radiated EMI.

8) Use linear power supplies. This is another "use unless impractical" choice. Linear supplies are inexpensive and quiet but they are large and heavy. Switching power supplies are very efficient, small, and light, but expensive and noisy.

Switching power supplies are, arguably, the leading cause of EMI in electronic products. They operate at high frequencies. They use high power. They have inductors that carry lots of current. They couple the switching noise directly into the power source. So, they are a significant generator of both conducted and radiated EMI.

Spread Spectrum Oscillators

There is a somewhat controversial oscillator available that is being marketed as an aid in reducing EMI. These are the "spread spectrum" type. The controversy comes because the reduction in EMI is really only due to the measurement techniques. Here's why.

These oscillators are not perfectly fixed in frequency. Rather, they dither slightly about a center frequency. On the average, they are as stable as crystal oscillators. But, from millisecond to millisecond, they shift frequency slightly. Hence the name, spread spectrum.

It's clear that the energy being radiated is always the same. Just the frequency is changing. However, when measuring EMI emissions, a spectrum analyzer is used. This sweeps through a frequency range and measures the signal strength at each frequency. The key is that the spectrum analyzer expects the measured frequency to be fixed. But, it isn't. The result is that the oscillator moves out of the analyzer's measurement bandwidth before the analyzer takes a full reading. This causes the analyzer to show a lower signal strength. That's why it's controversial. (And yes, this can and does affect computer timing.)

Conducted EMI

Mostly, we've talked about radiated EMI. Generally, this is the most difficult to control or suppress because it has many sources and many points of entry. Conducted EMI has very specific routes. By definition, it is conducted to something else through a wire. Since there is a limited number of interconnections, there are a limited number of points to control. (And, by definition, a battery-operated device that is not connected to another device cannot be a source, nor be affected, by conducted EMI.)

Motors are probably the largest source of conducted EMI. And, here there is a blurring between EMI and "clean power." Voltage sags or surges may not be technically classified as EMI. (Noise spikes definitely are.) Nevertheless, these too have to be considered as part of the operating environment. The causes and defense from these is different, however, and will not be discussed further here.

Another source of conducted EMI is intentional. This is "carrier current" transmitters that impress a signal into the power lines. College radio stations, as well as some hobbyist transmitters are sometimes this type. They purposely couple an RF signal directly into the electrical wiring of a building. And, there are some LAN (Local Area Networks) and security systems that communicate with each other using the same method. Will your product work properly if there is a large one-MHz signal coming in through the AC mains?

EMI and Security

One rarely considered aspect of EMI is that it can broadcast your secrets. Electronic espionage is a very serious concern for the government

REFERENCES

The Code of Federal Regulations 47, Parts 0 to 19 from the US Government Printing Office details the US/FCC rules and regulations concerning radio frequency emissions and other topics. It is available online at ***http://wireless.fcc.gov/rules.html.***

and it has its roots in spy chasing after World War II. Probably the first example of this was recognizing that receivers usually emitted the local oscillator signal back through the antenna. The larger the antenna, the greater the signal. This would allow someone nearby to determine what frequency the receiver was tuned to. So, if you knew at what frequency the spy's orders were sent, you could determine if your suspect was listening at the proper time and on the proper frequency. (This has been done.)

This has been taken to a higher level with the advent of computers, but not in the way you might think. Computers, especially the earlier mainframe types, are prolific generators of EMI. If you bought a computer that was identical to your target's computer, you could measure the EMI for every op-code and keystroke. Once you had that information, you could monitor the EMI of your target's computer and figure out exactly what it was doing. This would provide an almost unimaginable wealth of information. In the 1970s and 1980s, the US Defense Department took this very seriously (and probably still does). Equipment had to be "TEMPEST" rated so that its EMI could not be monitored. Specific information about TEMPEST concerns was (and probably still is) very highly classified.

EMP

While rare EMP (ElectroMagnetic Pulse) and induced EMI should be mentioned. Obviously, a nuclear detonation creates a powerful EMP. And, for obvious reasons, designing non-military products for this is not reasonable. However, smaller EMPs do occur on occasion. Typically, this is in conjunction with a large spark, such as lightning or other very significant power source. Note, this is not directly from a power surge through conductors (antennas, phone lines, power lines, etc.). Instead, it is induced, like a transformer, indirectly.

When this happens, inductors are affected and can generate large currents, as well as large voltages. This can do damage to themselves or other components. Clearly, this is difficult and usually impractical to design for.

Lighting the Way

Finally, EMI concerns can be eliminated if you substitute light for electricity. If you use optical fibers instead of wires, there can be no conducted EMI. (Yes, I know light is electromagnetic in nature, but we're using the FCC definition.) This is an expensive choice, but there may be occasions where it is cost-effective.

Conclusion

EMI is an environmental concern that touches a large number of areas. It is important that the designer of any electronic product consider it. The US Government, as well as most other countries and the European Union, have standards that define limits to EMI. And, designers should have a passing familiarity with these rules, at least. If you fail to think about EMI in the design stage, you'll probably be thinking a lot about it in every other stage. **NV**

Tech Forum

QUESTIONS

I'm studying for my Technician class license and am learning CW for the purpose of emergency operating. Does anyone know of a plan for a CW transmitter that a beginner could make at home for a relatively low price?

#08031 Jessica Stamper
via Internet

I have two transceivers that use an op-amp for switching between the RX and the TX control lines. The problem that I have run into is that the Windows-based programs that I would like to use (hyperterminal and Procomm) do not allow or have controls for CTS (clear to send) or RTS (request to send) which is used in RS232-type communications.

Is there a circuit that I can purchase or build that would act as a buffer, as well as a timer for the CTS and RTS lines that I need to control the transceivers that I am using?

I am using a baud rate of 9600 and the radio specs say that a time of 5-10 mS is required for lockup of the radios.

#08032 calvin@cyberport.com
via Internet

The PLL system of my beloved Kenwood R-5000 SW receiver went out (the display blanks out after a second, like the manual says), and I discovered that Kenwood OEM PLL boards are dreadfully expensive.

There are five phase loops in this system, but I'm certain only one or two components are bad among the hundreds on the board. I have a factory manual and have access to (and able to use) an oscilloscope, VOM, etc., but have no idea how to begin debugging the circular system. It does not look like the Kenwood web site will help.

#08033 G. Santa
Naperville, IL

Is there any way I can increase the speed of the uplink connection to my server? I am using the WINVNC software. When I dial out, I connect at 50 kbs. However, when I dial into my server, I connect at 26.4 or 28.8. I know it has something to do with a half duplex connection.

#08034 Gerry Ceccarini
via Internet

I have a personal DVD player and my sister stepped on the screen. Is there a place that might offer a replacement? The manufacturer won't sell just the screen. I've tried EarthLCD and they were very helpful, but did not carry a replacement.

#08035 Jeremiah Simmons
via Internet

I have a RadioShack Model 42-3069 strobe unit. I would like the schematic and suggestions about how to make it operate as a slave flash unit.

#08036 Russell Ferguson
via Internet

I want to construct a pocket-size one-octave electronic "pitchpipe," very simple with no bells and whistles. Is there an IC on the market that would be the basis for such a device?

#08037 David Niles
dabaniles@cox.net

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

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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.

ANSWERS

[5032 - MAY 2003]

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?

I do electronic repair and this has been the hardest piece of *equipment to get information on.*

A schematic of the DCT 1134 digital cable converter is available from Bomarc Services, **www.bomarc.org**. This is a company that publishes schematics of popular electronic products whose schematics are not published by the manufacturers. According to their web site, they even have schematics of the Sony Playstation 1 game system.

When going to Bomarc's web site, watch out for pop-up ads, and be sure to say "no" to the one that wants to install clock synchronization software on your PC; if you install it, it will presumably keep displaying ads forever.

Michael A. Covington
Athens, GA

[5034 - MAY 2003]

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?

#1 There are small printed circuit boards called surfboards available for adapting surface mount components for use with a breadboard. Digi-Key 33008CA-ND for an eight-pin surface mount device, for example, is a good choice. Digi-Key and other companies have many types available. Look at their catalog and/or website to get an idea of what is available and what would best suit your needs. To use a surfboard, you solder the surface mount component to one part of the PCB. Another part of the PCB has pins spaced for insertion into a solderless breadboard.

Here is how I solder surface mount components. Use a small-tip soldering iron and small-diameter solder:

1. Tape the PCB to your work surface so it won't move while you're working on it.

2. Melt a small amount of solder onto one pad of the PCB.

3. Place and hold the component on the PCB using tweezers. Remelt the solder you applied in step #2. Make sure that all the pins are lined up with the other pads. Since you already have solder on the pad, you can hold the tweezers in one hand and the soldering iron in the other. You don't need anyone else to hold any solder.

4. Now solder all remaining pins. The first connection you made will keep the IC in place.

5. Finally, go back and re-solder the first pin you did to make sure that there is a good electrical connection.

As for improving your soldering skills, all I can suggest is practicing.

David Hruska
Libertyville, IL

#2 Answer #1: Use 'Surfboard,' available from Digi-Key (page 919, Jan.-April 2003 catalog), **www.digikey.com**. The surfboards convert a variety of surface mount (SMT) footprints to Single In Line (SIP) format. The SIP format is compatible with solderless breadboards. Some surfboards are just the SMT footprint and enlarged solder pads.

Answer #2: Use the SMT prototyping adapters from **www.beldynsys.com** (advertised in *Nuts & Volts*). There is a large variety of footprints.

Mort Arditti
Los Angeles, CA

#3 Breadboarding adapters for surface mount to thru-hole are available from Capital Advanced Technologies, URL: **www.capitaladvanced.com/**. There is a list of distributors on the website.

Russ Kincaid
Milford, NH

[5036 - MAY 2003]

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.

#1 Ten LEDs as a turn signal: You could buy very nice looking turn signal modules from a motorcycle shop, but they cost from $35.00 to $100.00 per 12 LED module. You could put five LEDs in series and limit their current with a 470 ohm, 1/2 watt resistor. The numbers I used for calculating are: A 12-volt lead acid battery can reach 15.5 volts while charging, five LEDs in series need about 6.25 volts, and most LEDs must not be allowed more than 20 milliamps. This design keeps the LED current between 10 and 20 milliamps for any battery voltage from 11 to 15.5 volts. Be sure to measure the actual voltage used by the LED string. They can vary enough to need a different resistor value.

Chuck Larson
Largo, FL

#2 As for the turn signal application: If you wanted to use a "stock" turn signal assembly that uses LEDs instead of incandescents, you can get LED lamp clusters with standard mounting bases. Sunbrite, for example, has single- and bi-color clusters with wire leads, mini wedge, midget flange, screw (E10), and bayonet (BA9S, BA15) bases. They are available in a variety of colors, sizes, and brightnesses.

For a daylight-visible application, I'd suggest high-intensity LEDs, 1200MCD at least, higher if possible. Digi-Key (**www.digikey.com**) carries Sunbrite LED clusters.

American Opto Plus (**www.aopinc.com**) has some nice Outdoor Lamp Clusters.

These aren't incandescent lamp replacements, they are self-contained modules with wire or cable connections. Some models include two different color LEDs in one module, to combine say red brake lights with a yellow turn signal.

If you really want to implement your turn signals with discrete LEDs, my earlier advice still holds: use at least 1200MCD LEDs, or brighter if you can.

As for the inspection panel lighting: Depending on what you are trying to accomplish, you have a lot of options.

I assume using a simple flashlight is impractical for one reason or another (lack of space, need both hands free, whatever).

Would you be inspecting something in the dark, like during a blackout? If that's the case, you might opt for bright but diffused red LEDs to preserve your night vision. Or are you looking into a dark space in an otherwise well-lit area, like under a desk or inside a cabinet? In that case, bright white LEDs may be best. In any case, the LEDs probably wouldn't need to be quite as bright as your turn signals.

As for power, I had a similar problem at a job once, where I needed to inspect equipment in a darkened lab. I needed power, not just light, so I carried a portable battery pack with a cable and connector that mated to the equipment. This was convenient because everything I needed to work on was in one or two rooms. Not having to run more wires was an added bonus.

Mark Dobrosielski
Bradford, MA

[5038 - MAY 2003]

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 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?*

A series resonant L-C shunt circuit tuned to 400 Hz will reduce the fundamental dramatically. I built one for a military lab about 15 years ago, trying to clean up some unshielded 600 ohm audio circuits. Although it knocked down the 400 Hz audio by about 28 dB, it did NOT solve the problem.

Unfortunately, the 400 Hz signal was not a sinewave.

It was rich in harmonics at the source (an electronic frequency converter) and, even with the fundamental attenuated, the harmonics alone were nearly as annoying.

With the tuned circuit connected, listeners perceived the tone as being about half as loud as before — not nearly enough to call the problem solved.

Sorry, but I think your aircraft audio will be the same and a shunt would be even less effective there, since the headphone circuit is lower impedance than the one in my lab. Even if you boldly tried to trap out the fundamental and the audible harmonics, you'd need a big box of components and you'd have darn little audio left.

Active filters, although smaller than discrete component filters, have much lower Qs, require a power source, and may be drifty. If you go for higher Q with multi-section active filters, alignment becomes an issue.

In the absence of something I missed, you will just have to gut this one out.

John Markham
Chula Vista CA

[5039 - MAY 2003]

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.

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?

#1 JKL Components Corp., stocks a wide range of mini compact flourescent lamps and inverters for LCD back lighting applications. It would probably be best to replace the entire assembly (lamps and inverters) because it hasn't been determined the cause for inverter failure.

You can get a service representative at JKL to recommend a suitable replacement. But I caution you on lamp selection. Most lamps have a different color rating measured in Kelvin temperature output. If a higher or lower Kelvin lamp is selected, the color on the LCD will not look right and possibly not balance out right with the availabel settings range. So be sure JKL offers a return policy.

Their address is JKL Components Corporation, 13343 Paxton St., Pacoima, CA 91331-2376, or **www.jkllamps.com**.

Larry Wheeler
Ft. Stockton, TX

#2 The 15.1" LG flat panel would have a part number such as LM151X2 [last digit may vary]. Check the Micro Semi web page at: **www.microsemi.com/products/backlight/panellist.asp.**

Their link was broken to search by manufacturer, but I have provided the information here, as well as a direct link to their panel list database.

They sell inverters such as lxm1623-12-6x documented as: www.microsemi.com/datasheets/lxm1623-12-6x.pdf.

They document the connector pinout as: 1:high, 2:nc, 3:gnd. You might also send a query to **www.earthlcd.com** as they sell many LCD panels, controllers, kits, etc.

Barry Cole
Camas, WA

[50310 - MAY 2003]

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.

The BASIC in the TRS-80 Model 4 has the ON x GOTO and ON x GOSUB commands.

```
10 A=INT(RND(3))
20 ON A GOTO 40, 50, 60
30 PRINT " NOT ONE, TWO OR THREE " : END
40 PRINT " ONE " : END
50 PRINT " TWO " : END
60 PRINT " THREE " : END
```

A bit of logic and mathematical manipulation can get this to do the work in most situations.

Zoltan Ori
Morehead, KY

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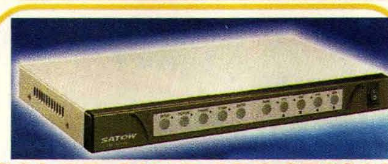

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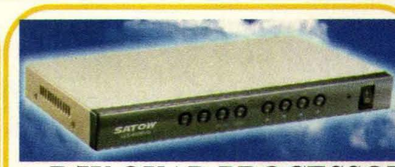

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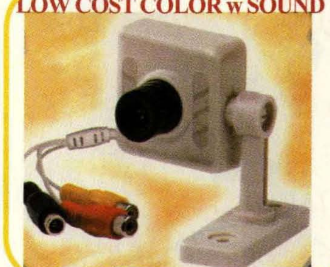

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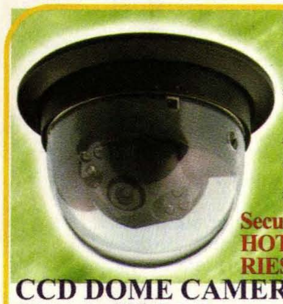

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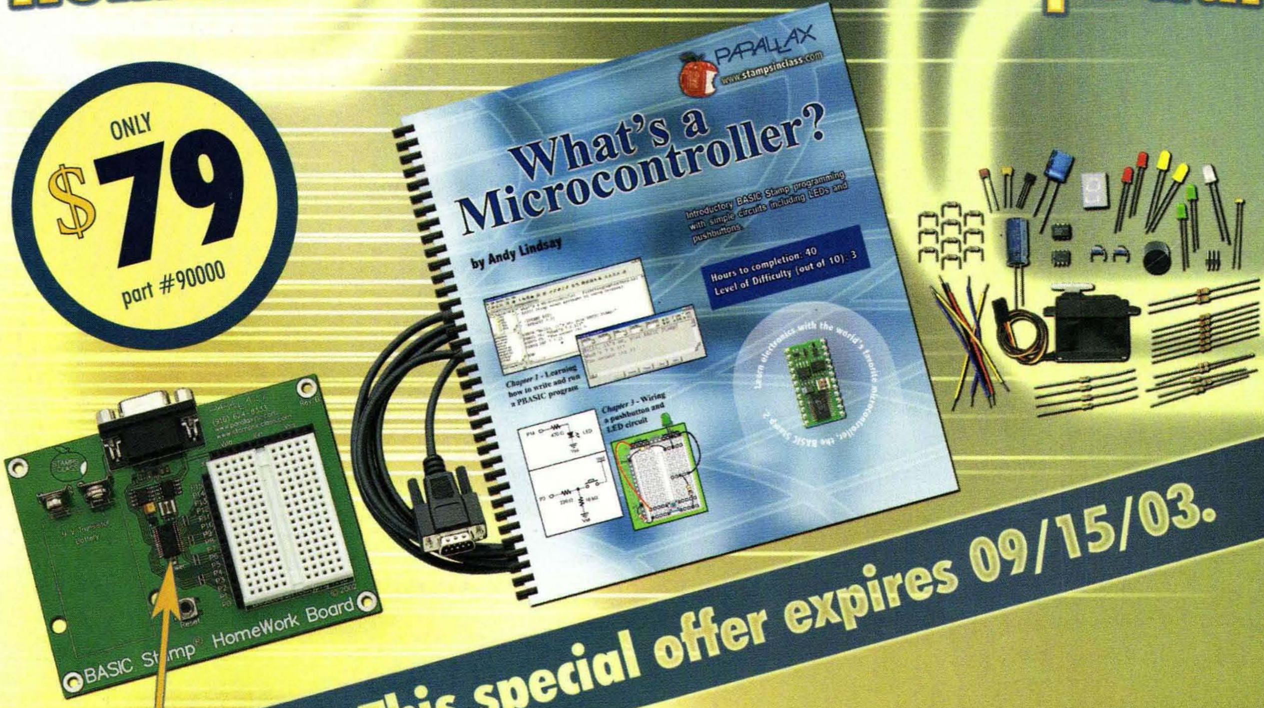

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