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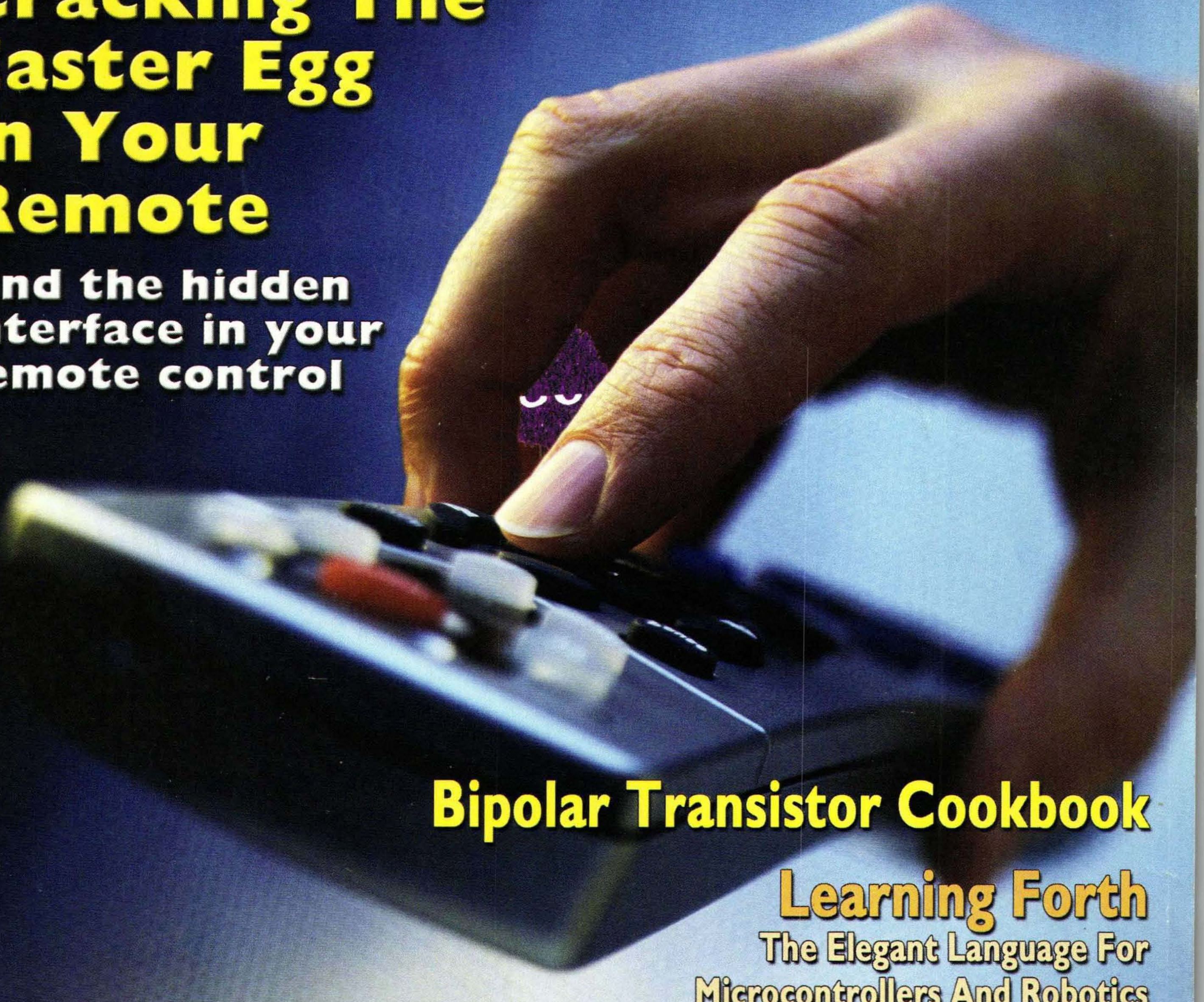
Everything For Electronics

Nuts & Volts

July 2003

Cracking The Easter Egg In Your Remote

Find the hidden interface in your remote control



Bipolar Transistor Cookbook

Learning Forth

The Elegant Language For Microcontrollers And Robotics

An RC Failsafe You Can Build

Failsafe devices are key to safety in radio-control applications

Electronics Q&A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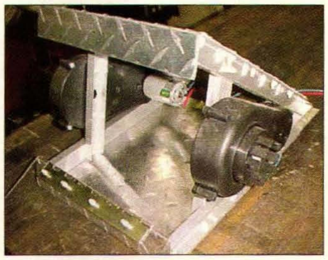

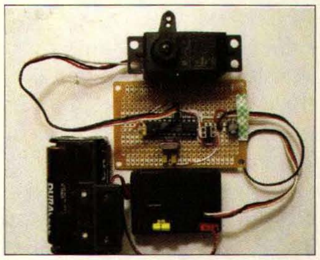

PROJECTS

Reader Feedback

Dear Nuts & Volts:

I read "Build a Negative Ion Generator," by Anthony Caristi, Apr. '03 *N & V*. I see one little problem in the parts used (a problem which I found several years ago in another project), the maximum voltage ratings of carbon resistors. The maximum voltage ratings differ for different manufacturers and different types of resistor construction, but the highest rating for 1/2-watt resistors is about 250 volts. (Carbon composition resistors have higher ratings than the more common carbon film.)

The article specifies 1/4-watt resistors for R6 through R11, and 1/4-watt resistors have lower voltage ratings than 1/2-watt resistors (one- and two-watt resistors have higher ratings). Using only six resistors places nearly 1,100 volts across each resistor at an output of 6,600 volts.

To prevent flashover under high humidity, the builder should use about 20 two-watt resistors with a total resistance of 60 megohms, or use special high-voltage resistors. High-voltage resistors are hard to find, but are sometimes available as surplus. The newest catalog from Electronic Goldmine (**www.goldmine-elec.com**) lists several made by Caddock that would be useable. (Those with resistances near 10 megohms are rated at 2 kV.) They don't list any at exactly 10 megohms, so it would be necessary to change the value of R12 so that the ratio of (R6 through R11) to (R12) remains at 600 to 1.

Bill Stiles, via Internet

Response:

The reader is correct about the voltage rating of 1/2- and 1/4-watt resistors. However, I used the resistors specified in the parts list simply because these parts are readily available, and are low in cost. It would be difficult to obtain and use 20 two-watt resistors, and the printed circuit board would have to be much larger.

The voltage rating of resistors would have to be addressed if this unit was to be commercially manufactured, but I have built two of these units with no voltage breakdowns even when the high voltage was adjusted to over 7,200 volts.

I thank the reader for his comments.

Anthony Caristi

Dear Nuts & Volts

I have been a confirmed electronics enthusiast/ham radio operator for over 45 years. I have seen many publications come and go. I have watched your publication evolve over the past few months and am pleased with your progress.

I hope you are successful with your new format and absorption of *Poptronics*. I enjoy construction projects of all kinds. Test equipment and techniques are always appreciated. I enjoy in-depth technical descriptions of projects and new devices. Don't be afraid to challenge the newcomers.

Keep up the good work.

Bob Dornan WA2EKU

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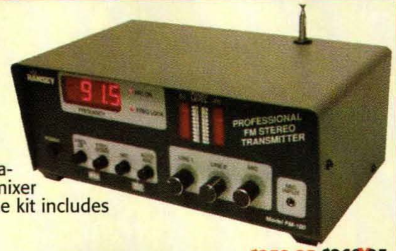
Professional FM Stereo Radio Station



- ✔ Synthesized 88-108 MHz with no drift
- ✔ Built-in mixer - 2 line inputs, 1 mic input
- ✔ Line level monitor output
- ✔ High power version available for export use

The all new design of our very popular FM100! Designed new from the ground up, including SMT technology for the best performance ever! Frequency synthesized PLL assures drift-free operation with simple front panel frequency selection. Built-in audio mixer features LED bargraph meters to make setting audio a breeze. The kit includes metal case, whip antenna and built-in 110 volt AC power supply.

Beat The Heat SALE! Expires 9/30/03

FM100B	Super-Pro FM Stereo Radio Station Kit	$259.95	$269.95
FM100BEX	1 Watt, Export Version, Kit	$329.95	$349.95
FM100BWT	1 Watt, Export Version, Wired & Tested	$399.95	$429.95

Professional 40 Watt Power Amplifier

- ✔ Frequency range 87.5 to 108 MHz
- ✔ Variable 1 to 40 watt power output
- ✔ Selectable 1W or 5W drive

At last, the number one requested new product is here! The PA100 is a professional quality FM power amplifier with 30-40 watts output that has variable drive capabilities. With a mere one watt drive you can boost your output up to 40 watts! And this is continuously variable throughout the full range! If you are currently using an FM transmitter that provides more than one watt RF output, no problem! The drive input is selectable for one or five watts to achieve the full rated output! Features a multifunction LED display to show you output power, input drive, VSWR, temperature, and fault conditions. The built-in microprocessor provides AUTOMATIC protection for VSWR, over-drive, and over-temperature. The built-in fan provides a cool 24/7 continuous duty cycle to keep your station on the air!

Beat The Heat SALE! Expires 9/30/03

PA100	40 Watt FM Power Amplifier, Assembled & Tested	$549.95	$599.95

Synthesized Stereo FM Transmitter

- ✔ Fully synthesized 88-108 MHz for no drift
- ✔ Line level inputs and output
- ✔ All new design, using SMT technology

Need professional quality features but can't justify the cost of a commercial FM exciter? The FM25B is the answer! A cut above the rest, the FM25B features a PIC microprocessor for easy frequency programming without the need for look-up tables or complicated formulas! The transmit frequency is easily set using DIP switches; no need for tuning coils or "tweaking" to work with today's 'digital' receivers. Frequency drift is a thing of the past with PLL control making your signal rock solid all the time - just like commercial stations. Kit comes complete with case set, whip antenna, 120 VAC power adapter, 1/8" Stereo to RCA patch cable, and easy assembly instructions - you'll be on the air in just an evening!

Beat The Heat SALE! Expires 9/30/03

FM25B	Professional Synthesized FM Stereo Transmitter Kit	$119.95	$139.95

Tunable FM Stereo Transmitter

- ✔ Tunable throughout the FM band, 88-108 MHz
- ✔ Settable pre-emphasis 50 or 75 μSec for worldwide operation
- ✔ Line level inputs with RCA connectors

The FM10A has plenty of power and our manual goes into great detail outlining all the aspects of antennas, transmitting range and the FCC rules and regulations. Runs on internal 9V battery, external power from 5 to 15 VDC, or an optional 120 VAC adapter is also available.

Beat The Heat SALE! Expires 9/30/03

FM10A	Tunable FM Stereo Transmitter Kit	$34.95	$39.95
CFM	Matching Case & Knob Set for FM10A		$14.95
FMAC	110VAC Power Supply for FM10A		$9.95

Professional Synthesized AM Transmitter

- ✔ Fully frequency synthesized, no frequency drift!
- ✔ Ideal for schools
- ✔ Microprocessor controlled

Run your own radio station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area. It is widely used by schools - standard output is 100 mW, with range up to ¼ mile, but is jumper settable for higher output where regulations allow. Broadcast frequency is easily set with dip-switches and is stable without drifting. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply!

Beat The Heat SALE! Expires 9/30/03

AM25	Professional Synthesized AM Transmitter Kit	$89.95	$99.95

Tunable AM Transmitter

- ✔ Tunes the entire 550-1600 KHz AM band
- ✔ 100 mW output, operates on 9-12 VDC
- ✔ Line level input with RCA connectors

A great first kit, and a really neat AM transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! One of the most popular kits for schools and scouts!

Beat The Heat SALE! Expires 9/30/03

AM1	Tunable AM Radio Transmitter Kit	$29.95	$34.95
CAM	Matching Case & Knob Set for AM1		$14.95
AC125	110VAC Power Supply for AM1		$9.95

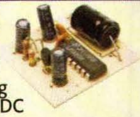
Mini-Kits... Fast, Easy, FUN!

Tickle-Stick

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC

TS4 Tickle Stick Kit $12.95

Super Snoop Amplifier



Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output. Makes a great "big ear" microphone. Runs on 6-15 VDC

BN9 Super Snoop Amp Kit $9.95

Dripping Faucet NEW!

Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Runs on 4-9 VDC.

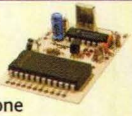
EDF1 Dripping Faucet Kit $9.95

LED Blinky

Our #1 Mini-Kit for 31 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Runs on 3-15 VDC.

BL1 LED Blinky Kit $7.95

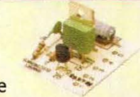
Touch Tone Decoder



Strappable to detect any single DTMF digit. Provides a closure to ground up to 20mA. Connect to any speaker, detector or even a phone line. Runs on 5 VDC.

TT7 DTMF Decoder Kit $24.95

Electronic Siren



Produces the upward and downward wail of a police siren. Produces 5W output, and will drive any speaker! Runs on 6-12 VDC.

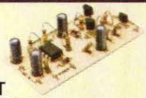
SM3 Electronic Siren Kit $7.95

Universal Timer

Build anything from a time delay to an audio oscillator using the versatile 555 timer chip! Comes with lots of application ideas. Runs on 5-15 VDC.

UT5 Universal Timer Kit $9.95

Voice Switch



Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch, or to turn on a recorder or light! Runs on 6-12 VDC and drives a 100 mA load.

VS1 Voice Switch Kit $9.95

Tone Encoder/Decoder

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Runs on 5-12 VDC and will drive any load up to 100 mA.

TD1 Encoder/Decoder Kit $9.95

RF Preamplifier

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.

SA7 RF Preamp Kit $19.95

Touch Switch

Touch on, touch off, or momentary touch hold, your choice! Uses CMOS technology. Runs on 6-12 VDC and drives any load up to 100 mA.

TS1 Touch Switch Kit $9.95

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TechKnowledgey 2003

Events, Advances, and News From The Electronics World

Advanced Technologies

Nuclear Fusion Still on the Agenda

A 2-mm plastic capsule shell sits atop a Lincoln penny with an inset of an X-ray image from the hot-imploded capsule. The smaller, bright image of the X-ray core is consistent with a 7x reduction in size through the implosion process. Photo by Diana Schroen. Courtesy of Sandia National Labs.

In recent years, the concept of harnessing nuclear fusion for power generation has received diminished public attention. But progress is still being made. In particular, scientists at Sandia National Laboratories (**www.sandia.gov**) recently announced, at a meeting of the American Physical Society, that Sandia's "Z machine" offers the possibility of controlled nuclear fusion. The machine has successfully created a hot dense plasma that produces thermonuclear neutrons, which emanate from fusion reactions within a BB-sized deuterium capsule placed within the target of the huge machine.

According to Sandia, compressing hot dense plasmas that produce neutrons is an important step toward realizing ignition — the level at which the fusion reaction becomes self-sustaining. A larger version of the Z machine might produce high-yield fusion — the state in which much more energy is released than is needed to provoke the initial reaction. The excess energy could be used for applications such as the generation of electricity.

More conventional fusion devices cause reactions either by confining low-density plasmas in dimensionally huge magnetic fields, or by focusing intense laser beams on the target (laser fusion). The Z machine, however, simply applies a huge pulse of electricity, very precisely timed. The pulse creates an intense magnetic field that crushes tungsten wires into a foam cylinder to produce X-rays. The X-ray energy, striking the surface of the target capsule embedded in the cylinder, produces a shock wave that compresses the deuterium within the capsule, fusing enough deuterium to produce neutrons.

The action takes place within a container the size of a pencil eraser, called a "hohlraum," at the center of the Z machine — itself a circular device about 120 feet (36.6 meters) in diameter. Pulsed power electrical systems have always been energy rich but power poor," observed Ray Leeper, a Sandia manager.

That is, we can deliver a lot of energy, but it wasn't clear we could concentrate it on a small enough area to create fusion. Now it seems clear we can do that."

New Cancer Treatment Uses Californium-252

Things are looking a little brighter for patients who suffer from incurable brain tumors and certain other cancers that are not easily cured by conventional treatments. A new treatment called "neutron brachytherapy" has been developed by the US Department of Energy's Oak Ridge National Laboratory (**www.ornl.gov**) and Isotron, Inc., of Alpharetta, GA. The treatment involves delivering concentrated californium-252 neutrons to the tumor site instead of treating it with gamma rays or photons, which generally are not as effective in killing cancer cells. Cancers most resistant to the conventional treatments include brain tumors, melanoma, sarcoma, certain types of prostate cancer, locally advanced breast cancer, cervical cancer, and cancer of the head, neck, and mouth.

The key development is a reduction in the size of the californium-252 source to a diameter of about 1.4 mm — half of the previous minimum. This allows physicians to insert the radioisotope through a catheter, directly into the tumor. ORNL and Isotron's success is the result of development and testing that began in 1999 with the signing of a three-year cooperative research and development agreement. The developers envision their treatment being useful for treating many of the some 257,000 combined cases of prostate cancer, cervical cancer, brain tumors, and melanomas that, as of 1998, claimed 64,700 lives per year in the US alone.

They are especially encouraged about the prospects of the treatment helping patients with glioblastoma multiforme — the most common primary brain tumor. It is extremely resistant to conventional forms of treatment, and the five-year survival rate is less than one percent.

Computers and Networking

Silent Computer Introduced

The Hush Mini-ITX computer reduces noise and mechanical complexity. Courtesy of Hush Technologies.

As long as five years ago, the *British Journal of Psychology* reported that excess noise can degrade the performance levels of office workers by as much as 60 percent. If you have experienced dysfunctionality as a result of cooling fan noise, power supply hum, and other PC-related sources, then a new desktop computer from Hush Technologies (**www.hushtechnologies.net**) may be just what you need. The PC is designed for environments in which noise is particularly problematic, including medical, mass media, and creative workplaces.

The Hush Mini-ITX machine uses a finned case and a special cooling system that eliminates the fan and reduces the number of moving parts to improve both noise levels and product reliability. The standard configuration includes a single disk drive (up to 200 GB) — a slim-line drive bay that accommodates a CD/DVD mechanism — and the usual memory options.

External dimensions of the case are only 370 mm wide, 340 mm deep, and 59 mm in height (14.6 x 13.4 x 2.3 inches).

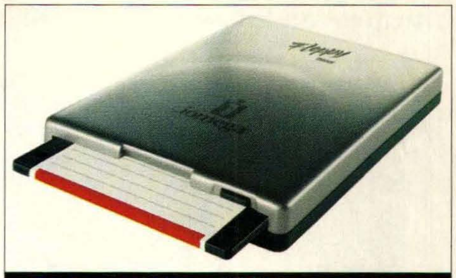
The CPU is a 933 MHz VIA C3 processor, built in Taiwan by Via Technologies. Prices start at about $750.00 for the basic version, which comes with a 40 GB Seagate drive, four USB 2.0 ports, two Firewire ports, S-video out, six-channel audio, and 10/100 Base-T Ethernet. You can upgrade to 512 MB of RAM for an extra $92.00.

For an additional charge, the machine can be shipped with Windows XP Home ($115.00) or Professional ($200.00), in English or German. Prices do not include shipping from Germany (the factory is located in Stuttgart, down the road from the Mercedes and Porsche facilities) or whatever taxes your government decides to add. Of course, to enjoy the full effect, you will have to shut down all other noise sources in the room, including radios, fans, air conditioners, printers, external hard drives, scanners, and the flapping mouths of your family or co-workers.

External USB Floppy Drive

The trend in computer design is to eliminate the familiar floppy disk drive, leaving you with nothing but CD/DVD media and networking for file transfer.

Unfortunately, millions of people all over the world still have drawers and filing cabinets full of floppies, which remain the most convenient method of transferring small files from one computer to another.



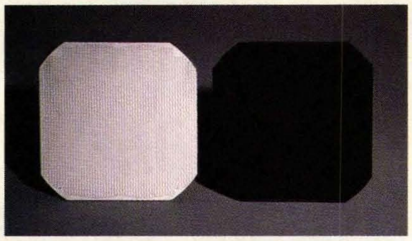
The Iomega Floppy USB-Powered Drive lets newer PCs swap files with older units. Photo courtesy of Iomega Corp.

But you can return to days of old and keep those floppies spinning with the Iomega® (**www.iomega.com**) Floppy USB-Powered Drive. The device, introduced in May 2003, uses a one-cable connection that allows users to connect it to a computer using any USB 1.0/1.1 port. Because it is host-powered, no additional adapters, batteries, or external power supplies are needed.

The drive is hot-swappable and cross-platform compatible with Microsoft Windows 98/98SE/2000/ME/XP, as well as Mac OS 9.1/9.2.2/10.1 and 10.2. The Iomega Floppy drive will read and write to all standard 3.5-inch floppy disk formats. The suggested retail price is $49.99.

Circuits and Devices

Improved Silicon Solar Cell



SunPower's new A-300 provides 20+ percent efficiency. Photo courtesy of SunPower.

SunPower Corporation (**www.sunpowercorp.com**) has announced the availability of sampling quantities of its A-300 device, which it claims to be the world's most efficient low-cost silicon solar cell. Based on a rear-contact design that maximizes the working cell area, hides wire, and facilitates automated production, the A-300 achieves better than 20 percent efficiency, which compares favorably to the standard 12 to 15 percent range for similar devices. According to SunPower, the National Renewable Energy Laboratory (NREL) has verified 20.4 percent conversion efficiency for the A-300.

The 125-mm, single-crystal A-300 cell generates three watts of electricity. This means that it can deliver three kilowatts from less than 17 square meters, making it suitable for rooftop systems, communications, building integrated PV systems, and consumer applications. SunPower cells have been used in a broad range of high-profile, high-performance products, including NASA's Helios solar airplane. As of this writing, the A-300 was scheduled to be available in limited quantities by the time you read this. Production quantities are expected to be available in 2004.

"World's Smallest Logic IC" Offered in New Package

Philips Electronics (**www.semiconductors.com**) has announced an expanded version of its family of logic integrated circuits with the addition of a 24-pin "depopulated very-thin quad flat-pack no-leads (DQFN)" package. Designed for logic gates, octals, and medium-scale integration, the DQFN package is designed to address the continuing demand for smaller electronic products and components. The 24-pin DQFN package has a footprint of only 3.5 x 5.5 mm. In addition to size reduction, the DQFN package is said to offer improved heat dissipation and easier board assembly. The package incorporates an exposed die paddle, providing a 20 percent improvement in heat dissipation over a comparable TSSOP package. The package has no leads, which eliminates co-planarity and bent-lead issues. The first products available in the new package are the 74LVC543ABQ, 74HC154BQ, and 74HCT154BQ devices. For details on these, and other logic devices from Philips, you can visit **www.semiconductors.philips.com/logic**.

Industry and the Profession

Bell Labs Receives its 30,000th Patent

Lucent Technologies (**www.lucent.com**) recently announced that the company has been granted its 30,000th US patent. This milestone patent covers mechanisms for guaranteeing quality of service in Internet Protocol (IP) networks. Until recently, IP-based networks were designed to provide "best effort" service for data applications, but could not provide the higher level of quality required by public switched telephone network (PSTN) applications such as interactive voice, video, and multimedia. This patent covers mechanisms for guaranteeing quality of service in IP networks. Specifically, this is achieved by establishing a virtual channel in which information flows uninterrupted between a sender and receiver. Since 1925, Bell Labs (now a Lucent division) has patented a string of technological breakthroughs including the transistor, the charged coupled device (CCD), the UNIX® computer operating system, the C programming language, the laser, communication satellites, and cellular telephony. Nearly 10,000 scientists and engineers currently work at Bell Labs, with most focused on developing new communications products and services for Lucent and researching technical issues such as network security, reliability, and efficiency. Last year, Lucent was awarded nearly 700 US patents across a broad range of disciplines. Recent patents include designs for flexible electronic displays using organic semiconductors, software debugging tools, microelectromechanical devices that can modulate optical signals to increase network speed, and others.

$30 Million Superconducting Cable Project

American Superconductor Corp. (**www.amsuper.com**) has been selected by the US Department of Energy (DOE) as prime contractor for a high-temperature superconductor (HTS) power transmission cable project in the Long Island Power Authority (LIPA) transmission grid. The power cable system is said to be the world's first installation of a superconductor cable in a live grid at transmission voltages.Capable of powering 300,000 homes, the 2000-foot (610-meter) transmission circuit will be located underground in an existing right of way in East Garden City, Long Island, NY. With a capacity of 600 MW, the 138-KV superconductor cable system will be an integral part of the LIPA grid, and is expected to be installed and operating by the end of 2005. The $30 million cost may seem a little steep, as it comes to about $15,000.00 per foot. But superconductor cables typically carry three to five times more power than conventional cables of the same size and can be installed in existing rights of way, helping reduce the cost and environmental impact of grid upgrades. The DOE will provide approximately $15 million toward the cost of the project. NV

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Circle #111 on the Reader Service Card.

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

Stamp Applications

You've Got Robot Eyes

How about something simple this month, yet useful and even fun? Good — I've had a crazy couple of weeks leading up to writing this, especially the last few days. Today, I told my best friend, Farah, that the only thing stopping me from throwing myself from the balcony is the thought that falling just three stories would only add painful injury to the string of insults [uncooperative projects] I've been dealing with for the past several days ... Zoiks.

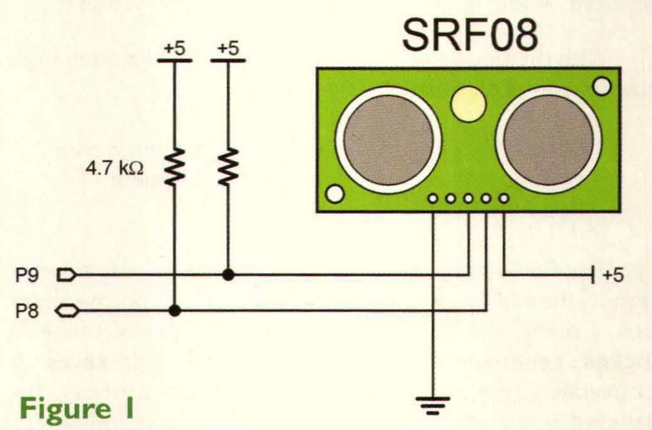

Figure 1

Now, things haven't been all bad. The other day I received a package from my friends in Holland (I conducted some BASIC and Javelin Stamp training sessions there in February). Among the goodies were some great books ... and books are just about my favorite thing in the whole wide world next to BASIC Stamps. The book that I've really been enjoying while on my reading breaks is *The I2C Bus* (ISBN 0-905705-47-5), published by *Elektor Electronics* magazine. If you've not seen *Elektor*, it is to Europe what *Nuts & Volts* is to the United States — a high-quality electronics magazine that targets serious hobbyists like you and me.

Thumbing through the various I2C projects in the book encouraged me to spruce up my BASIC Stamp I2C library (for non-BS2p/pe Stamps), to take advantage of PBASIC 2.5, to put aside my various uncooperative projects, and to try the Devantech SRF08 ultrasonic range finder that's been begging me for some attention.

The SRF08 is physically identical to the SRF04 we experimented with last year, but its two-wire connection is an I2C bus instead of a trigger input and pulse output. The advantage for us is that we can connect up to 16 SRF08s on the same two wires. This is perfect for an array of robot "eyes."

Let's get right to it. Figure 1 shows the connections that will work with our BS2/BS2e/BS2sx I2C routines, as well as I2COUT and I2CIN on the BS2p and BS2pe.

What's Your Address?

Since we discussed I2C bus details last year, I won't go into that, except to remind you that I2C devices have a slave address (device code) and internal register addresses. Most I2C devices have external address pins that allow us to set the device address (a few devices have fixed addresses — like the CMPS01 from Devantech). With the SRF08, we must set its address electronically, through the I2C bus.

If we have only SRF08 in a project, we can use the default address, $E0, and deal with the range finder — much like an I2C EEPROM. To use more than one on the same bus, of course, necessitates an address change in one or more units. This is actually very simple to do. What is required is the transmission of a specific byte sequence ($A0, $AA, $A5) to the command register ($00), followed by the new address (there are 16 valid choices). Here's the code:

```
FOR idx = 0 TO 3
  i2cSlave = $00
  i2cReg = RegCmd
LOOKUP idx, [$A0, $AA, $A5, NewSRF08], i2cData
  GOSUB Write_Byte
NEXT
```

The slave address used by this routine is the "broadcast" address ($00) that will act on any SRF08 (more on this later). Once the address is set, it's a good idea to give the use a method of verification. Luckily, the SRF08 has an onboard LED that blinks when its slave address is received. We can cause this LED to blink by putting the code into a loop that writes a valid command to the SRF08 command register.

```
 DO
  i2cSlave = NewSRF08
  i2cReg = RegCmd
  i2cData = $50
  GOSUB Write_Byte
  PAUSE 65
LOOP
```

When power is cycled on the SRF08, the LED will display a code of long and short blinks that indicates the slave address setting. It is a good idea, however, to mark the device after we've changed the address — this will make things easier later.

How Far to the Next Obstacle?

With the device address set, reading the distance from the sensor to an obstacle is a simple process:

- Send a ranging command to the desired device.
- Wait 65 milliseconds for the measurement.
- Read the range.

The first step is to send a ranging command. In addition to the ability to control multiple devices on the same bus, I really like this feature — we can specify range in inches, centimeters, or in microseconds. This saves us conversion math in PBASIC. To start the process, the ranging command ($50 for inches, $51 for centimeters, $52 for microseconds) is written to the command register at [internal] address $00. After 65 milliseconds, the ranging value is ready and we read the two-byte range value from registers $02 and $03. If you look closely at the SRF08, you'll see a CdS photocell nestled neatly between the ultrasonic elements. This is another nice feature of the SRF08 — each time a range measurement is made, the light falling on the photocell is measured and placed in register $01. This will be an eight-bit value that will get larger as more light falls on the photocell.

Since the program is fairly short, we can print most of it [sans I2C routines] here. This set-up code takes care of formatting our DEBUG terminal screen and displaying the revision code of the SRF08. The revision code is read from register $00 (same address where we write the command value).

```
Setup:
  DEBUG CLS
  DEBUG CrsrXY, 0, 0, "Devantech SRF08 Range Finder Demo"
  DEBUG CrsrXY, 0, 1, "---------------------------------"

  i2cSlave = SRF08
  i2cReg = RegCmd
  GOSUB Read_Byte
  DEBUG CrsrXY, 0, 3, "Rev Num... "
  DEBUG DEC i2cData, ClrEOL

  DEBUG CrsrXY, 0, 5, "Light..... "
  DEBUG CrsrXY, 0, 6, "Range..... "
```

The main code sends the ranging command (inches), gives the SRF08 the time it needs to make the measurement, then reads back and displays the light and measurement values. The guys at Devantech have made the SRF08 a breeze to use.

```
Main:
  i2cSlave = SRF08
  i2cReg = RegCmd
  i2cData = RngIn
  GOSUB Write_Byte
  PAUSE 65
  i2cReg = RegLight
  GOSUB Read_Byte
  DEBUG CrsrXY, 11, 5, DEC i2cData, ClrEOL
  i2cReg = RegRange
  GOSUB Read_Word
  DEBUG CrsrXY, 11, 6, DEC i2cData, " in.", ClrEOL
  GOTO Main
```

Now, what if we want to talk to more than one SRF08? Do we need to address them and wait for each one? No. Remember I mentioned the "broadcast" command earlier? All we have to do is send a ranging command to the broadcast address ($00), wait 65 milliseconds, then loop through each of our sensors and read its range value.

```
Read_Sensors:
  i2cSlave = $00
  i2cReg = RegCmd
  i2cData = RngIn
  GOSUB Write_Byte
  PAUSE 65
  FOR idx = 0 TO 2
    LOOKUP idx, [$E0, $E2, $E4], i2cSlave
    i2cReg = RegRange
    GOSUB Read_Word
    sonar(idx) = i2cData
  NEXT
```

Remote Robot Start With a Laser

Many of the contests conducted by the Dallas Personal Robotics Group give a few extra points to robots that can be started without touching them. At a contest some months back, DPRG member David Anderson (a great robot builder and programmer) asked me if I had a laser pointer with me. As it happened, I did have one in my toolbox. He smiled, pointed it at his robot, and away it went — extra points scored.

Remember a couple months ago when I talked about learning through imitating? Well, that's what I did with David's laser trick. Since the SRF08 is a great robot part and it has a CdS photocell, I wrote a short piece of code that lets us handle "non-contact" starts.

The concept is simple: read the ambient light on start-up, then wait until there is a significant rise in the light level. This rise, of course, will be caused by the laser pointer hitting the CdS. In my code, I decided a 25 percent change is significant. You may need to adjust for the ambient lighting in your situation. A smaller percentage change will make the trigger more sensitive. Be careful though, as too small a change could make the remote start subject to false triggering.

Here's the code that reads the ambient light and

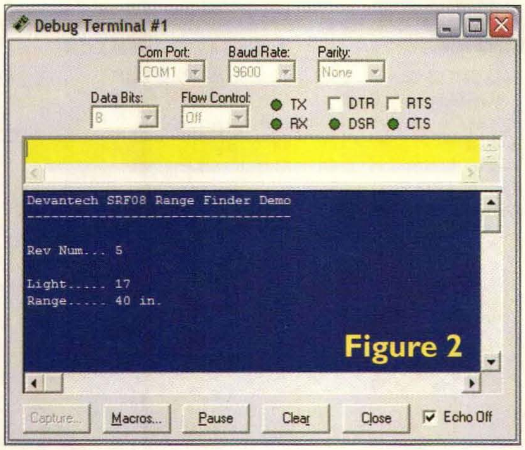

Figure 2

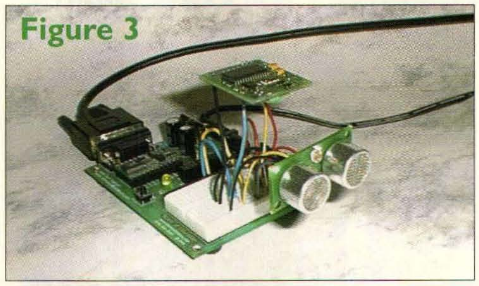
Figure 3

Resources

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

establishes the start threshold of 125 percent:

```
Setup:
  i2cSlave = SRF08
  i2cReg = RegCmd
  i2cData = RngIn
  GOSUB Write_Byte
  PAUSE 65
  i2cReg = RegLight
  GOSUB Read_Byte
  thresh = i2cData.LowByte */ $0140 MAX 255
```

The next step, then, is to monitor the light level until the threshold is exceeded.

```
Wait_For_Start:
  DO
    i2cSlave = SRF08
    i2cReg = RegCmd
    i2cData = RngIn
    GOSUB Write_Byte
    PAUSE 65
    i2cReg = RegLight
    GOSUB Read_Byte
  LOOP UNTIL (i2cData >= thresh)
```

See? I told you this was going to be easy. It's really a credit to Devantech and the work they put into the SRF08. And bear in mind that the SRF08 is capable of more than we've covered here — but these are the features that are most useful. The documentation and Devantech web site cover advanced features like multiple echoes.

For fun, I've included a photo of my test BOE with an SRF08 and CMPS01 — just to make sure they "play nice." Of course, they do. Now I just need to strap it onto a BOE-Bot chassis and let it tear around my apartment. After I do that, I think I'll attach a big laser and target some of those uncooperative projects that have been troubling me for the past several days. I'll let you know how that goes.

Until next time, Happy Stamping. **NV**


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Amateur Robotics

Getting Started In Combat Robots — Part 2

Last month, I talked about the sport of combat robotics. I pointed out several places to find out about local competitions. I chose a style of bot and strategy for this project, and have decided on the radio control system and drive motors. Now, let's talk more about motors, speed controllers, and batteries.

Figure 1. Original and Modified Colson Wheels. Shows two different Colson brand caster wheels. The inner plastic hub is very sturdy. The outer layer of rubber is a good match for traction and strength. The large wheel has been modified with a milling machine to make the plastic hub thinner for a better fit on the custom axle for this particular bot. The small wheel has not been modified and will be used on a different project. Before modification, the hubs on both wheels are similar. Can be purchased at **www.botparts.com** (Part #BPDWC20) or **www.teamdelta.com** (Part #RCM307).

Motors, Wheels, and Speed Controllers (Continued)

I chose to use a solid plastic wheel with rubber tread. It is called a Colson Caster wheel, and is in heavy use among veteran bot builders. The Colson can be picked up at several locations on the net, but it doesn't come in 7.64-inch diameters. The next one is an eight-inch diameter. That will give us a little more speed.

If you go with the Colson, you should put it on a milling machine and shave off the raised parts of the plastic hub. This will give you a flatter surface for mounting a hub and axle.

Normally, you will want to do some calculations to figure out whether or not the motor is strong enough to carry the weight of your bot. Since two of these motors can carry a child and the car for which they were intended, I'm certain they can power a 12-pound bot. Since the bot is so light and we've increased the motor's power by increasing the voltage, they should power the bot to top speed very quickly.

If you aren't going to use these motors, you should find out the stall torque of the ones you will use. Stall torque will be relatively low if you use a motor without gearing. Building your own gearbox or setting up a chain and sprocket reduction isn't for the beginner, so I suggest you find a motor with a gearhead already attached. NPC.com carries several gearhead motors that are used by many veteran bot builders.

If the motor will develop 8 lb-ft of torque, and the gear ratio is 15-to-1 (15:1), then the torque output at the axle is 120 lb-ft. Divide that by the radius of your wheel and you have the amount of torque at the ground or 30 lb-ft for a wheel eight inches in diameter. Remember that you have to divide the motor's RPM by the gear ratio to find the shaft RPM. If it's too slow, you need to find a new motor with either a faster RPM or a stronger torque.

Notice that I use stall torque instead of peak torque. It is a well-known rule of thumb in the combat robot community that you should design to carry twice the weight of your bot. Doing this using stall torque as a starting point will give you acceptable acceleration rates and acceptable power without diving into a lot of complicated mathematics.

The complication with this combination of wheel and motor is the axle and hub. The Colson has a large round bore. The motor box has a strange, five-sided, rotating plastic piece that is supposed to turn the wheel. There is a stationary nylon bushing inside the five-sided spinning part on the motor. The nylon bushing has a 0.43 inch diameter hole in it for an axle. I had to come up with a mounting scheme that keeps the wheel on an axle and mates it with the motor. My final design was made from two pieces. My axle is a straight piece of round steel turned down on a lathe to fit the 0.43 inch bushing. On that axle, I mounted a specially-made aluminum part.

Half of the aluminum part is machined with five sides so that it fits the gear housing. The other half is machined to fit the bore of the Colson wheel. That half has a small flange on the inside with a bolt pattern drilled in

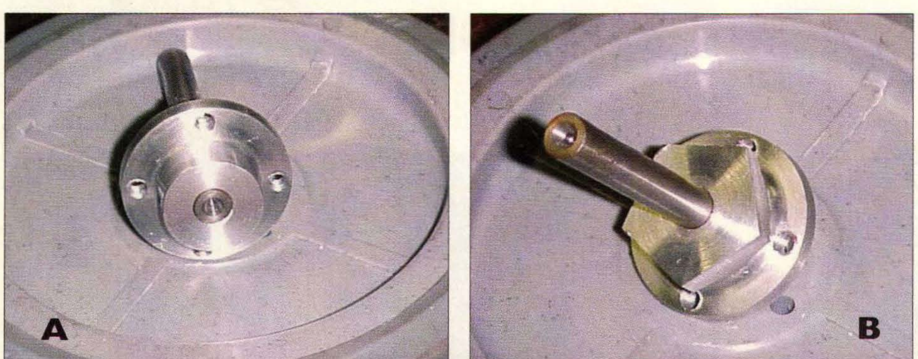


Figure 2. Custom Hub and Axle Parts A and B. Part A shows the round side of the hub with the bolt pattern. This end is secured in the wheel by four bolts. Part B shows the pentagon-shaped hub that mates with the pentagon-shaped drive piece of the motor. The axle is made of steel and is pinned to the aluminum hub. This had to be made on a milling machine and a lathe. Purchased at Wilson's Welding of Linwood, NC — you should be able to find a local machine shop that can do the job.

it. The bolt pattern was marked on the Colson's hub. Then I drilled and tapped the hub for a 1/4-20 bolt to make sure it would stay on the aluminum part. The aluminum hub is pinned directly to the steel axle to form one piece. Once the axle/hub combination are inserted into the nylon bushing, I put an aluminum shaft collar on the opposite side of the axle. This keeps everything in place.

Normally, these motors have a 930 mA, no-load current draw. Since I'm doubling the voltage, the current draw doubles, as well. That means they will be drawing about two amps when spinning. Stall current is the most important thing to consider, though. When stalled on 12 volts, these motors draw about 20 amps. You must have speed controllers that can handle that amount of amperage.

You can measure the stall current with a calibrated resistor, or shunt. Simply connect the shunt in series with the motor and battery. While measuring the voltage across the shunt, stall the motor for a short time. The shunt I use is rated for 150mV per amp. If the measured voltage is 300mV, then the current draw would be two amps.

Builders use a variety of electronic speed controllers. The Vantec RDFR (at **www.Vantec.com**) is one of the old-school favorites. Vantec has speed controllers that run forward and reverse with built-in mixing capabilities. They have models that can handle more than 200 amps from five to 60 volts. They are fairly expensive — more than $300.00 for a unit that will handle only 60 amps or so. But, they do control two motors at once and can be plugged directly into your receiver. The Innovation First (**www.ifirobotics.com**) Victor and Thor speed controllers have been around in the USFIRST competitions for a while. IFI has controllers that can run on 12 or 24 volts. The Victor can handle about 60 amps (I've seen them handle 90, though), while the Thor is supposed to handle around 120. These controllers only handle one motor each, and there is no mixing function. Buying a pair of the Victors will cost about $300.00 too, but they can fit in a more compact space. They can also plug directly into your receiver.

The 4QD controllers (**www.4qd.co.uk**) are pretty much old-school too. They have lots of functions — including real current limiting. I believe they are the safest controllers to use since you won't be turning it into a piece of burnt toast when you stall large motors. They have units that run on voltages between 12 and 48, and currents between 0 and 300+ amps. They don't have mixing and they require a special interface board to hook up to a receiver. The interface board is available at **www.Delbots.co.uk** for around $100.00, though they don't list prices on their site for some reason. They were developed by the head technical guy for Robot Wars in the UK and have all the failsafe and mixing features built in.

The Open Source Motor Controller is a speed controller that can be bought in kit form or already built and tested from **www.Robot-Power.com**. Experts in the robot combat community developed this controller as an open source project. So, you can download schematics and build it yourself. It has lots of features and has been battle tested by several veterans, even though it is fairly new on the market. The last choice of speed controller is the type that R/C car enthusiasts use. These controllers boast very high maximum and continuous current capabilities — but don't be deceived. They are rated for very short periods of time (milliseconds) and can't handle the current they claim for the amount of time we need. That being said, they can handle the currents drawn by the motors I've chosen for this project. I bought a couple of DuraTrax Blast, Forward/Reverse universal electronics speed controllers from **TowerHobbies.com** for about $40.00 each. They can be plugged directly into your receiver and are even BEC equipped. If you want to use an

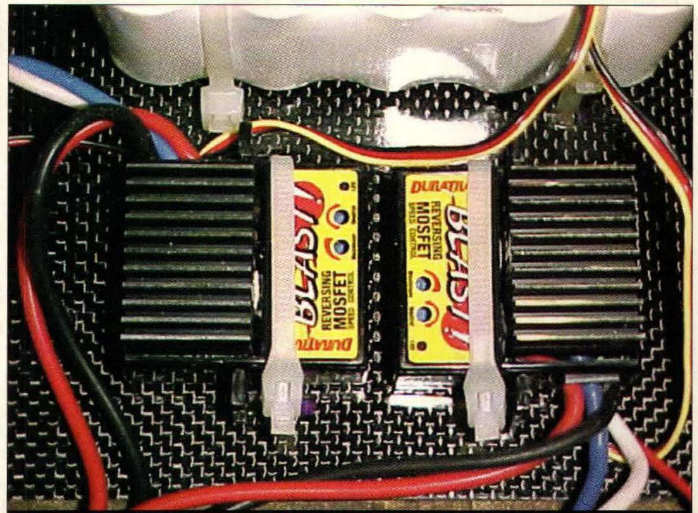


Figure 3. Duratrax Blast Electronic Speed Controllers. These are the MOSFET-driven, reversing speed controllers. Normally used in remote control cars, these controllers are only suitable for small bots. They have a receiver battery eliminator circuit built in and can be calibrated with a tiny screwdriver. Purchased at **www.towerhobbies.com** (Part #LXD526). (This part has been discontinued, but can be replaced with Part #LXAXT8 for $5.00 more each.)

Figure 4. Battlepack Batteries. Shows a 12-volt battery pack. The speed controllers I chose can only handle up to seven cells, so a custom pack will be necessary. I modified the pack myself so that I can use it again on a later project at the original voltage. Purchased at **www.battlepack.com**, custom packs can be ordered at no extra charge.

R/C car ESC, make sure it can run in both forward and reverse directions or it will be useless to you.

Batteries

You have three choices when it comes to batteries. They are all rechargeable. Normal alkaline batteries will not last long enough nor will they supply the amount of current a real bot needs to operate. Batteries with liquid electrolyte are specifically disallowed in the rules because of the inherent danger. If you smack one with an axe, the acid can spray all over the place. They have also been known to explode. Sealed Lead Acid (SLA) or gel-cell batteries are their close cousins and are okay for use in a combat bot. However, SLA batteries are normally too heavy for smaller bots.

Nickel Cadmium (NiCd) and Nickel-Metal Hydride (NiMh) batteries are currently in use in many bots. I've chosen the NiCd BattlePack from **www.BattlePack.com**. They can source around 80 amps for several minutes — more than enough for the motors I am using. If you are using larger motors that require more than 80 amps, you can wire the packs in series so that they share the current requirements. A battery pack like this will cost about $80.00. You can save a little cash by wiring cheap R/C battery packs, but once you get into larger bots, it will be worth it to check the BattlePack site.

Design Time

When you start choosing materials for a 12-pound bot, you are pretty much constrained to aluminum for the main structure. Steel is heavy and the pounds will add up after building the body and adding the wheels, motors, batteries, and armor.

Choosing Materials — There are a couple types of frames to choose from. The space frame can be made from individual parts welded together or cut from a solid billet of material. This type of frame usually requires the designer to draw it up on a CAD system first. I have done some CAD work, but I didn't want to do any for this project. That leaves me with a stick frame. The stick frame is welded, bolted, or riveted together. I chose to rivet this frame together because there were going to be some funky angles that would make it difficult to use a nut and bolt. I don't have a welding machine that can weld aluminum either. Normally, I wouldn't recommend rivets, but with such a light bot and some large rivets, I can pretty much assure myself that they won't pull out during an impact. The frame of the bot is made from 3/4-inch aluminum plywood channel. This is a piece of aluminum with a cross section shape of a squared off "C." You can buy it in six or eight foot long sticks for about $15.00 from your local hardware store. It is meant to fit over the edge of a 3/4 inch thick piece of plywood — sort of like a counter top edge.

I took several measurements and began marking the channel. You can easily cut this material with a hacksaw, but you should use a fine file to smooth the edges of the cuts. Once I had all the pieces cut, I started working on the angles to form the wedge.

Since I didn't have a CAD drawing to go by, I had to figure out how tall the back of the wedge needed to be. This was simple. The wheels are eight inches in diameter so the end of the wedge should be that tall. Mounting the motor and wheel combination a little bit inside the wedge would allow the wheels to extend above and below the flats of the wedge, as well as past the rear of the wedge. Each motor case was riveted to the same type of channel and mounted inside the "V" of the wedge. The whole thing now formed an "A" shape. The next step was to mount the armor, which also holds the two wheel/frame assemblies together.

Figure 5. 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.

Summary

This 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. You will most likely go with a different speed controller so that you can use 12 volts or more.

Next month, we'll wire up the electrical components and install some real armor. Once we get the bot working, I'll go into some methods of driving practice that will benefit you at a competition. I'll also show you the most common bot failures and talk a little bit about going to a competition. **NV**

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:

Simple solutions to not-so-simple problems. Use the ubiquitous 555 to build an earth ground ohmmeter, capacitance meter, and garage door alarm. Use it again to measure wind speed, count cans, or as a VCR time-lapse record switch. Power/signal diode selection simplified.

Simple Earth Ground Tester

Q. ARRL has published a circuit to test ground resistance. However, it involves the use of 110 volts AC. Not wanting to run around the yard with an extension cord, would you please suggest a battery-powered circuit that would economically measure ground resistance (in a three-electrode configuration) at 60 Hz to 200 Hz?

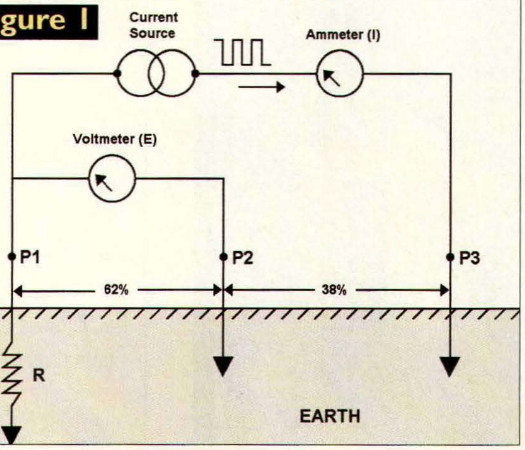
Dwight Holtzen CQN3ARU
via Internet

A. Yes, I have the circuit you request. But let me give the reader some background information on earth ground resistance before I spring it on them with no explanation of what in the world you're talking about. First, earth ground is used as a conductor in power distribution systems. Its purpose is to minimize the hazard of a lightning strike by grounding one leg of the AC line in soil. Second, radio waves use it too, as a ground plane to increase the effective radiation power of the antenna. In both cases, it's important to know the resistance of the soil and treat it with chemicals if the resistance is too low.

There are three ways to test soil resistance using two-, three-, or four-point measurment. The most popular is the three-point configuration (Figure 1). Its parameters are very well-documented, and it's easily implemented. You can think of it as a four-wire ohmmeter with two electrodes in common. The two outer electrodes establish a current in what can be considered an "earth" resistor.

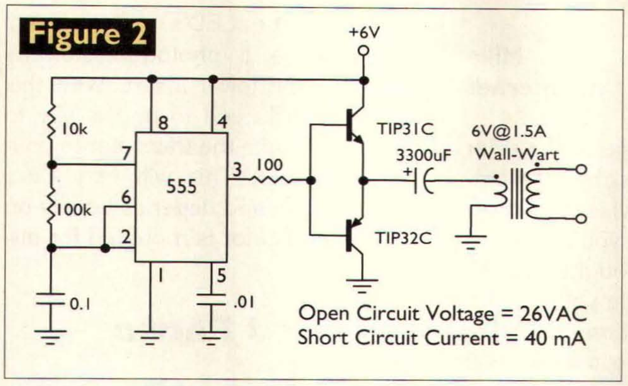
The voltage test point (P2) for three-point soil measurements is at 62 percent of the distance from the common probe (P1). The resistance is determined by using Ohm's Law (R = E/I), where I is the current flowing between P1 and P3, and E is the voltage between P1 and P2. When driving the stakes, it's essential that they be in a straight line — with P3 as far from P1 as practical (within limits — not the next county!). Unfortunately, I don't have room to discuss the effects of effective resistance zone overlap, but suffice it to say that the three-point method fairly compensates for it. As for the circuit (Figure 2) it delivers an output equal to that found in most portable ground resistance testers — 26VAC (open) at 40 mA (shorted). A single 555 astable oscillator provides a 60-Hz squarewave that drives a 6VAC wall-wart transformer. The transformer is available from All Electronics (800-826-5432; **www.allelectronics.com**), part number DCTX-615. The timing capacitor (0.1uF, pin 2) determines the frequency — reduce it to .05uF and the frequency increases to about 130 Hz. The rest is up to you and your Fluke (DMM).

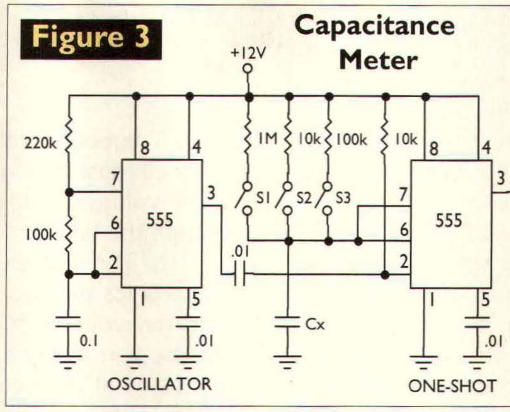
Figure 1



Simple Capacitance Meter

Q. I have a need for a simple capacitance meter. It doesn't have to have a digital readout or a microcontroller. A 555 timer chip with a whistle is more





S1	.001 - .01uF
S2	0.1 - 1.0uF
S3	.01 - 0.1uF

than adequate. A comparative tester is all I really need.

Bob Fredericks
via Internet

A. A capacitance meter using a 555 timer? This is a relatively simple design (originated by TI, I believe) with amazing accuracy. Basically, it consists of a monostable (one-shot) RC multivibrator clocked by an astable RC oscillator — both based on the 555 timer (Figure 3).

When the oscillator triggers the one-shot, it begins charging the unknown capacitor, Cx. The rate of charge is equal to t = RC, and the trigger point is t = 1.1RC. Because this is nearly a linear function, it's very easy to translate the value of the capacitor into a pulse width, which now becomes a PWM (pulse-width modulated) signal with the timing of the astable clock. From here, the output pulse is averaged by an analog voltmeter. If R is 100k and C is 0.1 uF, then the output voltage is 10 volts. Switches S1 through S3 expand the range to include capacitors with values ranging from 100 pF to 1 uF. Increasing and decreasing the value of R in increments of 10 can extend that range down to 10 pF and up to 100 uF. Be aware that at the bottom end (lower capacitance), the accuracy falls off due to stray capacitance and other lossy factors. To calibrate the meter, insert a 0.1 uF capacitor across Cx, select S2, and adjust the 5k pot until the 0-1 mA meter reads full scale. The accuracy of the meter between the ranges depends on the accuracy of the timing resistor, R. If you use 5 percent resistors, then expect up to a 5 percent error as you switch ranges.

The 12-volt line must be held constant using a voltage regulator, such as an LM78L12.

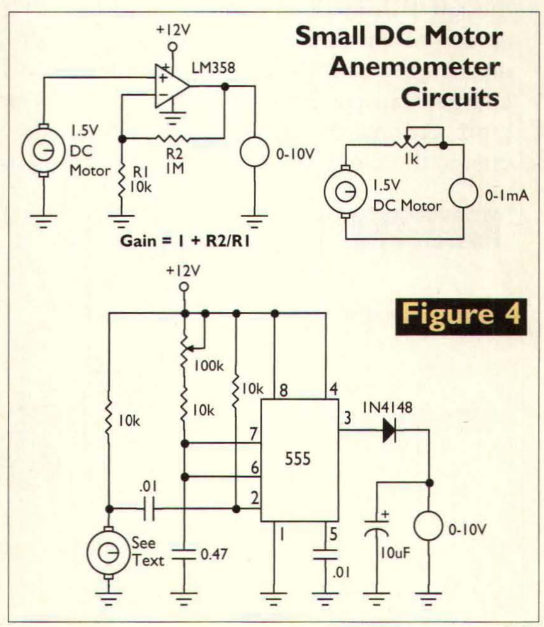
Simple Anemometer

Q. Recently I picked up a panel meter that registers 0 to 10 volts, but is calibrated 0-90 MPH. I think it would be really neat to make a wind speed indicator using it, but I'm at a loss as to what circuit to use and what to use as a generator. I'm thinking a DC motor of some sort. What do you have?

Wes Kranitz
Milwaukee, WI

A. I've used small, permanent magnet DC motors a lot to generate a linear voltage that indicates wind speed — anemometers they call them. Notice that I said *a lot*. That's because the brushes and bearings wear out in almost no time — six months at best. Fortunately, they are readily available from RadioShack, All Electronics, and others for a pittance — and they fit inside a PVC coupling for easy mounting. I have several circuits that work, but let's start at the beginning. First, I assume you already have the hardware — something like a wind-cup arrangement, or equivalent (**www.davisnet.com/weather/products/weather_product.asp?pnum=7903L**). Second, is this really a 0-10 voltmeter, or a 0-1 mA meter with a current limiting resistor? If you can find the meter's series resistor and short it out, it greatly simplifies the circuit. The 0-10 volt scale will require signal conditioning. The simplest circuit uses a small 1.5-volt motor across a 0-1 mA meter, with a series resistor to calibrate the scale (Figure 4). If this isn't enough voltage to tweak your meter, a simple op-amp can solve that problem (middle schematic). I'm sorry that I can't give you exact values — this is one of those cut-and-try circuits. Using a known wind speed, adjust the value of R1 until the meter reads the correct speed. Do this for two points (wind speeds) by adjusting R2 to obtain a linear scale. This will take some juggling.

In my later experiments, I used pulses rather than voltage to display wind speed. For this, I modified the commutator pads on the motor so that they formed an electrical contact (switch), rather than generate a volt-



age. This required the cutting of the wires from the coil to the pads and bending of the leads. The motor now becomes a rotating switch with make and break pulses. It proved more reliable and easier to calibrate. All you need is a 555 monostable multivibrator to measure wind speed (lower circuit). Again, you will have to experiment with the value of the .047uF timer capacitor and 100k potentiometer so that the pulse frequency of the modified motor matches the meter scale. Need a wind source for calibration? I hesitate to recommend a moving car, but with caution, it's the best method. You, being the copilot — *not* the driver — hang your head out the window with your contraption in hand, on a deserted stretch of road, and have the driver call out the MPH as you tweak the respective adjustments (you don't need to go faster than 30 MPH). Make a U-turn and do this again as many times as needed to average prevailing winds into your calibration.

Solar Panel Match-Up

Q. I'd like to recharge my NiCd 7.2 V battery for my mail alert (mounted inside my mailbox door) using a solar panel that I purchased from All Electronics Corp. The panel is rated three volts at 40 mA. Even though I installed two small signal diodes to prevent the battery from discharging at night, it still loses its charge. Can you help me with a diagram on how the solar panel could charge the battery to its full potential of 7.2 volts?

Mike
via Internet

A. The output voltage of the solar cell must be higher than the battery voltage, otherwise it won't charge the battery (as you've experienced). The unit you bought from All Electronics has too little voltage output for your application. In other words, you bought the wrong solar panel. What you need is the SPL-960, which outputs nine volts at 60 mA and sells for $5.25. Keep one diode (you don't need two).

Simple Garage Door Alarm

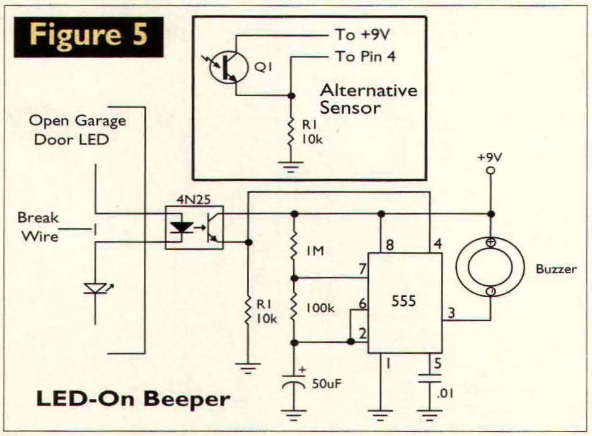
Q. I have a commercial gadget that detects when the garage door is open by lighting up an LED. Trouble is, I keep forgetting to look at the LED. I'd like to improve on the design so that it beeps every 60 seconds or so when the LED is lighted. Can you suggest a circuit that will sense when the LED is on and beep occasionally?

Tony Serra
via Internet

A. It all depends on the access you have to the LED and its associated circuitry. Ideally, you can splice into the LED line and insert an optocoupler — like the 4N25 — in which case, the circuit in Figure 5 is all you need. The LED inside the 4N25 is wired in series with your "Garage Door Open" LED, and lights every time your indicator lights. This causes the transistor to conduct, and applies voltage to the Reset pin (pin 4) of the 555, which turns it on. The circuit is an astable multivibrator with a time constant of 45 seconds off and five seconds on. That is, every 45 seconds the buzzer will sound for five seconds. Increasing the size of the 50uF cap will increase these times proportionally.

If you don't have access to the LED's wiring, you'll have to use a phototransistor, as shown in the lower insert. With this sensor, you'll need to find a way to optically couple the transistor to your LED indicator. This will vary from case to case, and depends largely on how the indicator is mounted for display.

Figure 5



LED-On Beeper

Salvaged Photo Switch

Q. I've salvaged a couple of photo switches and would like to make use of them for an application I have in mind. There is an LED on the end that lights up when a piece of reflective material is placed in front of the switch and goes out when blocked. I would like to be able to activate a relay when the beam is broken. I would also like to use the other switch to count the number of times an object passes by the beam. What I need from you are the circuits to fill my wishes. The switches are rated for 120 mA at 12-30 volts DC.

Jimmy
via Internet

A. I'm assuming the contacts are SPST (single-pole, single-throw) NO (normally-open). To detect if the beam is broken or not, use one of the circuits in Figure 6. In the Switch-Off/Relay-On circuit, the switch shorts the base of the relay driver transistor to ground when the LED is lit — unlit, the short is removed and the relay pulls in. In the Switch-On circuit, when the switch is closed, it supplies base current to the transistor when the LED is lit, causing the relay to pull in.

The event counter requires a one-shot monostable multivibrator, which is easily made using a 555 timer (Figure 7). Without it, the counter could lock up or be confused, should the object stop in the beam and remain there. For this design, I used an optocoupler input and a relay output because it interfaces with virtually all counters — both electromechanical and electronic. Each time the beam is broken, the relay contacts activate for about 100 mS. Because it is a reed relay, RadioShack 275-233 or equivalent — with very little back EMF — no suppression diode is needed.

VCR Switch Saves The Day

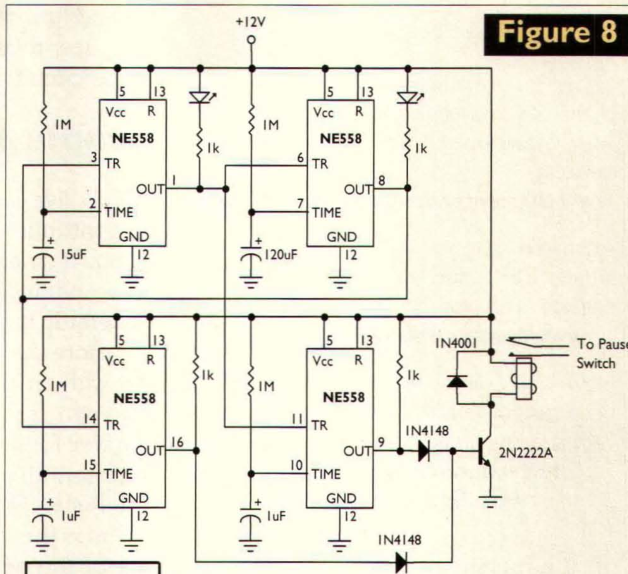
Q. I'm trying to convert my cheap VCR to a time-lapse recorder. Unlike commercial surveillance units that take a snap-shot frame every eight seconds, I want to record in real time (15 seconds), with pause times up to five minutes. I've figured out how to do it by pulsing the Pause button on and off using a relay across the switch's contacts. What I need is a circuit (preferably using a 555 chip) to automate the pressing of this button in increments of 15 seconds record, two minutes pause, 15 seconds record, two minutes pause, ad infinitum.

L. F. Duncan
Oceanside, CA

A. The best chip for this application is a 558 quad timer, which minimizes the parts count because it doesn't require coupling capacitors between stages. The top two timers (Figure 8) are connected in a ring counter, where the output of each feeds the input of the other. These outputs also feed the inputs of the two independent timers below, which are configured as monostable oscillators. Each time one of the monostable multivibrators is triggered by the ring counter, the relay NO contacts close for one second, which are wired in parallel with the Pause button on the VCR. The two 1N4148 diodes are wired together to form an OR circuit to drive the relay.

The values shown result in a record time of 15 seconds and a pause time of two minutes. Changing the value of the timing capacitor changes these times. Each uF represents one second (e.g., 15uF equals 15 seconds). The circuit is designed to engage the record timer (15 seconds) when power is first applied. If the VCR and timers get out of step, manually press the Pause button to resyncronize the two. If your VCR supports it, you can add a second relay (and 2N2222A transistor — remove the OR circuit) and assign each relay to the individual Record/Pause switches, in which case, the VCR and controller will always be in sync.

Figure 8



VCR Time-Lapse Controller

Struggling With Diode Selection

Q. I have been struggling with how to select diodes for the common application of blocking reverse voltage. It seems like, in most cases, the specs are so non-critical that the selection doesn't matter. But in the Apr. '03 column, there were two schematics in Figure 8 that specified two different diode values — 1N4148 and 1N4001 — and I am wondering why. In other simple circuit schematics, I see a mixture of diodes like 1N914, 1N4002, and 1N4003 specified, even though the circuit voltages are less than 14 volts. I have used diodes to block reverse connection at the input of my five-volt power supplies, and as flyback protection next to relays. In these cases, I've chosen the 1N4003 for its higher voltage rating. Is there an advantage to using one of the others? I feel like I am missing something here.

Judy May
via Internet

A. Several factors have to be considered when specifying diodes for an application — not the least of which is cost. As you point out, breakdown voltage is a primary consideration. The breakdown voltage (VR) is the maximum voltage you can apply across a diode in the reverse direction and still have it block conduction. If this voltage is exceeded, the diode goes into the zener mode and conducts current, rendering the diode useless as a rectifier. Exceeding the reverse voltage almost always destroys the diode by shorting it out. There is nothing gained by specifying a breakdown voltage that's greater than needed, that is, a 1N4001 (50 volts) will work equally well in a 12-volt circuit as a 1N4007 (1,000 volts) for about half the price. The reverse EMF of a 12-volt relay coil seldom exceeds 100 volts — the actual voltage is dependent on the size (inductance)

Figure 7

Event Counter

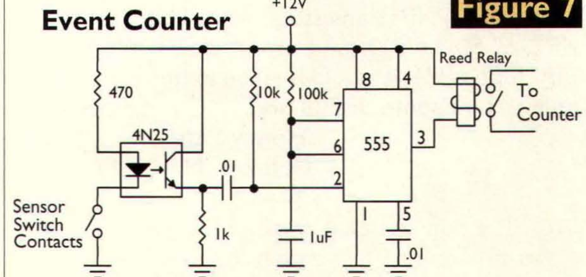
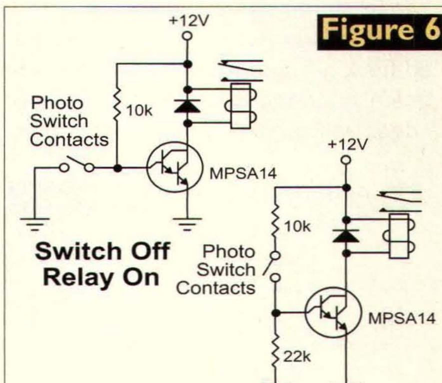


Figure 6



Switch Off Relay On

Switch On Relay On

Cool Web Sites!

Okay you trivia wunderkinds, here's your chance to challenge the quiz master with your knowledge of hollow and solid-state devices.

www.chipcenter.com/surveys/quiz.jhtml

Animated engines: These pages are an attempt to understand how mechanical engines of all types work.

www.keveney.com/Engines.html

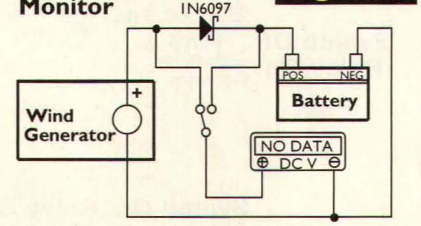
How smart are you really? This quiz has been testing "intelligence" for over 50 years with amazing accuracy.

www.dur.ac.uk/t.m.jackson/intelligentietest.htm

of the solenoid. The more metal inside the coil, the bigger the kick.

Of course, the forward current (I/O) rating must be greater than the current demanded by your load. If the current is more than the diode can supply, it overheats and quickly melts down to a shorted device. Diode meltdown in rectifier circuits can also happen if the reverse recovery time is slower than the frequency of the power source. One encounters this situation in power supply switching circuits, like those found in TV high-voltage flyback power supplies. The reverse recovery time is the time it takes a diode to go from forward conduction to reverse-blocking. If the turnaround time is too slow, current will flow in the reverse direction when the polarity changes, which heats up the junction, and eventually results in its demise. Not all diodes are designed to be power rectifiers. The 1N4148, for example, is a low-capacitance signal diode most often used in switching circuits, like those needed for logic steering. The low capacitance guarantees that the switching edges will be clean, with sharp turn-on and turn-off times. This is why you can see mixed diode types in the same circuit. I hope this helps.

Wind/Battery Monitor **Figure 9**



Simple Pleasures

Q. I live in Mexico, on the beach, without electricity or running water. I make my electricity with solar panels and an Air 403 wind generator that is capable of producing more than 40 amps, which I monitor with an analog ammeter and digital voltmeter. This system has served me well for nearly 10 years with nothing more than normal maintenance.

Recently, I've had a yearning to monitor the voltages at both the output of the generator and the battery bank. Presently, I can only monitor the battery voltage. What I need is a way to isolate the two. The only reason I want to monitor the output voltage is because, well, sometimes I get a little bored. Any suggestions?

Robert
via Internet

A. This is an interesting request with a simple solution. Insert a diode in the hot lead and use an SPDT switch to switch between the generator voltage and the battery bank, as shown in Figure 9. I would use a Schottky barrier diode, like a 1N6097 (available from Digi-Key), over a standard silicon rectifier to reduce heat and energy loss.

Who Sells Transistors With Two-inch Leads?

Q. Like the subject asks — where can I buy hobby-quality transistors with two-inch leads? I build simple projects using ugly point-to-point wiring construction. I am looking for NPN and PNP transistors with an HFE of 50 to 100, and an IC of 10 mA. If possible, it would be nice to be able to find some JFETs, too.

Henry Fales
Orleans, MA

A. The only people I know who sell transistors with two-inch leads is All Electronics, and they have a very limited selection. Might I suggest you extend the leads on what you have by adding a wire salvaged from a telephone cable (you know, the one with RGYB in the white jacket). Fashion a hook at the end of each so you have a good mechanical connection, then solder them together. This allows you to create leads of any length, and it provides desirable insulation needed for long runs.

MAILBAG

Dear TJ Byers:

I just received the latest issue of *Nuts & Volts* (April 2003) and saw your clever Inductive Wireless Headphone set-up. This will, of course, work in the form you presented. However, you can really jazz things up by inserting a 70-volt speaker line transformer between the power amp and the room loop antenna. Simply attach the eight-ohm tap to the amp and the 70-volt winding to the antenna.

Why does this work better? Because the eight-ohm transformer winding is a much better impedance match to the amp output. You may have to adjust the volume on the amp so that the transformer doesn't become saturated, which leads to distortion.

On the headphone antenna connection, add a tuning capacitor across the coil — a value somewhere between 100pF to about .0047uF will do the trick.

This is exactly the same principle used in commercial underground pipe locators used by utility companies. I repair these for a living, and was amazed when I opened my first commercial unit and found that the transmitter was simply a portable PA amp with the 70-volt output connected to the pipe to be located and ground. An audio amp was connected to a pickup coil that is moved overground to find the pipe.

I thought you would like to know your old science project came close to equipment that is in use everyday throughout the country!

Robert P. Kramer
via Internet

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Electronic Theories and Applications From A to Z

Let's Get Technical

Inside Protected Mode — Part 3

Exceptions, Interrupts, I/O, and Virtual-8086 Mode

by James L. Antonakos

This month, I conclude a three-part examination of protected-mode architecture. Previously, the mechanics of segmentation, paging, protection, and multitasking were covered. Here, I will present the details of exceptions, interrupts, I/O, and virtual-8086 mode, the last components of our tour through protected-mode architecture.

EXCEPTIONS AND INTERRUPTS

In this section, we will examine the operation of interrupts and exceptions in the Pentium's protected mode. An interrupt is generated in response to a hardware request on the INTR or NMI inputs, whereas an exception is generated during the course of execution. For example, divide error is an exception generated when the Pentium's DIV or DIVI instructions are executed with a divisor operand of 0. Let us examine how interrupts and exceptions are supported.

The Interrupt Descriptor Table — Real mode uses a 1KB interrupt vector table (IVT) beginning at address 00000H. Each four-byte entry in the IVT consists of a CS:IP pair that specifies the address of the first instruction in the interrupt service routine. An eight-bit vector number is shifted two bits to the left to form an index into the IVT. Protected mode relies on an interrupt descriptor table (IDT) to support interrupts and exceptions.

The IDT comprises eight-byte gate descriptors for task, trap, or interrupt gates. The IDT has a maximum size of 256 descriptors. The size of the IDT is controlled by a 16-bit limit value stored in the interrupt table descriptor register (ITDR). This 48-bit register contains the 32-bit base address for the IDT and the 16-bit size limit. Figure 1 shows how the IDTR is used to locate the IDT, which can be placed anywhere in physical memory.

The eight-bit vector number for the currently-recognized interrupt is shifted three bits to the left and used as an index into the IDT. Thus, vector 10H accesses the descriptor at offset 80H in the IDT. The LIDT (Load Interrupt Descriptor Table Register) and SIDT (Store Interrupt Descriptor Table Register) instructions are used in conjunction with the IDTR. Each instruction uses a single operand that specifies the address of a 48-bit memory word. This six-byte word is used to change the location of the IDT, or find its current address. LIDT may only be executed when the CPL is 0. SIDT can be executed anytime.

READIDTR: Reading and Displaying the IDTR — The READIDTR program uses the SIDT instruction to store a copy of the contents of the IDTR in memory, where it is then examined and converted into printable form.

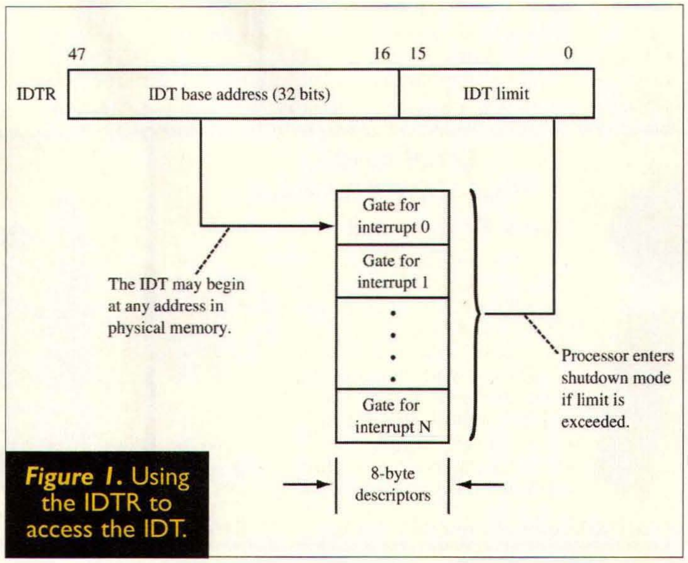

Figure 1. Using the IDTR to access the IDT.

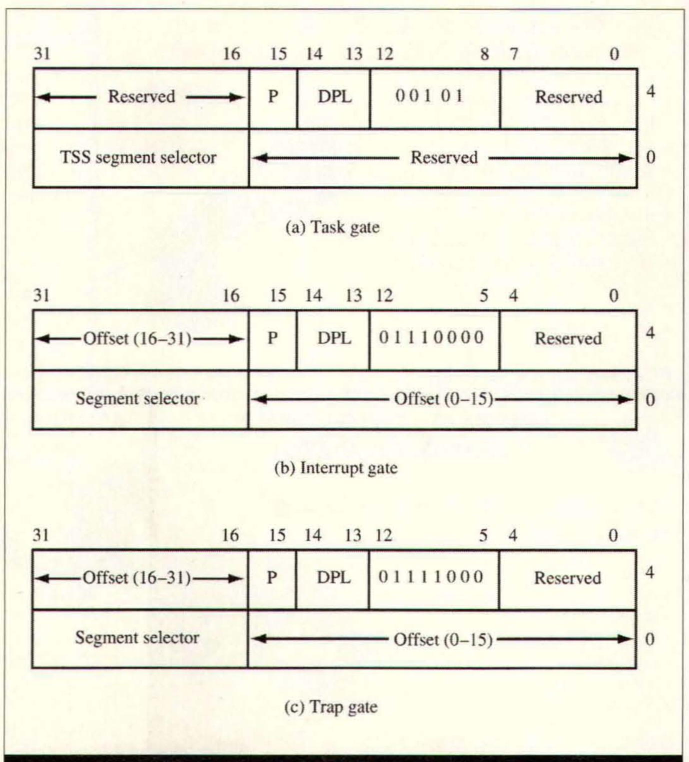

Figure 2. IDT Descriptors.

```
;Program READIDTR.ASM: Read and display contents of IDTR.
;
.MODEL SMALL
.586
.DATA
IDTRA   DW      ? ;storage for limit
                  bits
IDTRB   DD      ? ;storage for IDT
                  base address
MSG     DB      'The IDTR contains '
DB              8 DUP(?)
DB              ':'
DB              4 DUP(?)
DBASE   DB 0    DH,0AH,'$'
HEXTAB  DB      '0123456789ABCDEF'
.CODE
.STARTUP
SIDT    IDTRA           ;store IDTR
MOV     AX,IDTRA        ;load limit
                         bits
LEA     SI,DBASE-1      ;set up con-
                        version pointer
CALL    CONV            ;convert
                         limit bits
DEC     SI              ;skip over ':'
MOV     EAX,IDTRB       ;load IDT
                         base address
CALL    CONV            ;convert 32-
                         bit address
CALL    CONV
LEA     DX,MSG          ;display results
MOV     AH,9
INT     21H
.EXIT
CONV    PROC NEAR
MOV     CX,4            ;prepare for
                         4 passes
DIGIT:  MOV     DI,AX
                ;get a copy of input
AND     DI,000FH        ;mask out
                         offset
MOV     BL,HEXTAB[DI]
                ;load corre-
        sponding ASCII code
MOV     [SI],BL         ;save it in
                         buffer
DEC     SI              ;adjust
                pointer to buffer
SHR     EAX,4           ;get next
                         hex digit
LOOP    DIGIT           ;and repeat
RET
CONV    ENDP
END
```

When READIDTR is executed from DOS, the output looks like this:

The IDTR contains 00000000:03FF

If, however, you start Windows and run READIDTR from inside a DOS shell, you get a different result:

You can reach James Antonakos at **antonakos_j@sunybroome.edu** or visit his web site at **www.suny broome.edu~antonakos_j**.

The IDTR contains 8000DA70:02FF

This indicates that Windows — which runs in protected mode — has changed the nature of the underlying interrupt system.

IDT Descriptors — There are three descriptors that may be used within the IDT: task gates, trap gates, and interrupt gates. The format of each descriptor is shown in Figure 2. The P-bit in each descriptor stands for present, and indicates whether the segment is present in memory. The two-bit DPL field specifies the descriptor privilege level (0 is the highest). The 32-bit offset points to the first instruction in the handler's code segment.

The segment selector points to an executable segment selector in the GDT or LDT for interrupt and trap gates. The TSS segment selector for a task gate points to a TSS descriptor in the GDT. Interrupt and trap gates operate like a CALL to a call gate. Task gates operate like a CALL to a task gate. Once again, there may be up to 256 descriptors in the IDT. When fewer interrupts/exceptions are required, the limit field of the IDTR is used to specify the addressable limit within the IDT. The Pentium will enter shutdown mode if the limit is exceeded.

Interrupt and Exception Descriptions — Table 1 summarizes the protected-mode interrupts and exceptions available on the Pentium. Descriptions of these interrupts and exceptions are as follows:

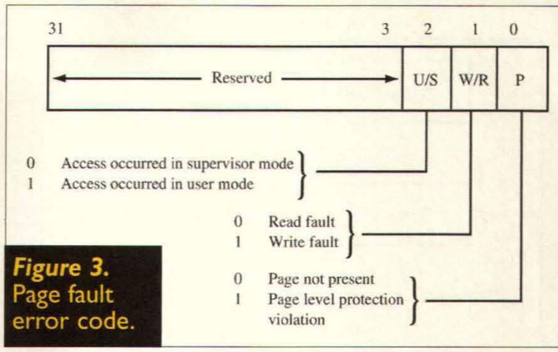

Figure 3. Page fault error code.

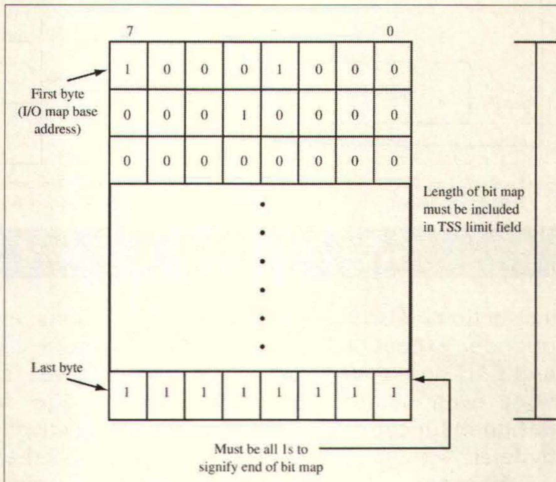

Figure 4. Sample I/O permission map.

Vector 0: Divide Error. This exception is generated when the divisor is 0 in a DIV or DIVI instruction.

Vector 1: Debug Exception. This exception has multiple uses during debugging. It is used for single-stepping, instruction, data, and task switch breakpoints.

Vector 2: NMI Interrupt. This interrupt is generated upon recognition of a rising edge on the Pentium's NMI input. NMI cannot be disabled through software (as the INTR interrupt can).

Vector 3: Breakpoint. This one-byte instruction (opcode CCH) can be used to trigger a debugging routine by replacing the first byte of an instruction (in RAM) with the CCH opcode. The breakpoint handler is responsible for replacing the original byte of the instruction that was modified when the breakpoint was set up.

Vector 4: Overflow. This exception is called when the INTO instruction is executed with the overflow flag set. Recall that the overflow flag is modified in accordance with the signed results of arithmetic and logical instructions.

Vector 5: Bounds Check. The BOUNDS instruction calls this exception when it detects an array subscript out of range.

Vector 6: Invalid Opcode. Any opcode not recognized by the instruction decoder generates this exception. In addition, using the wrong operand size in an instruction (presumably via self-modifying code) or using the LOCK prefix with the wrong

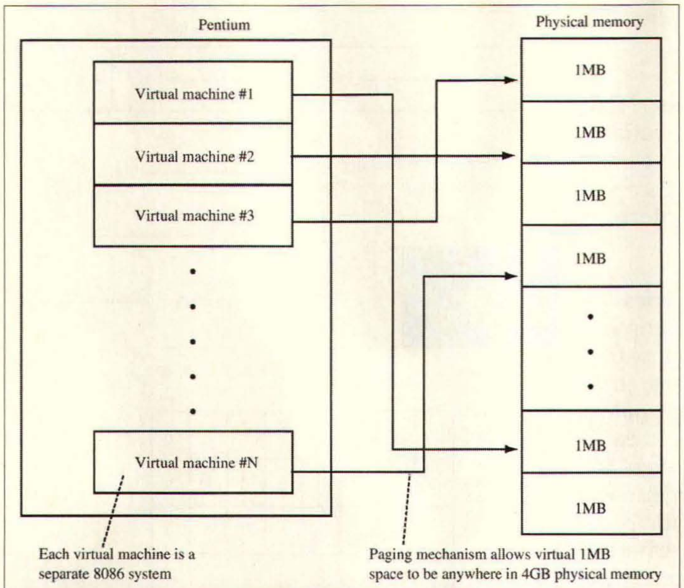

Figure 5. Concept of a virtual machine.

Table 1: Protected-mode interrupts and exceptions

Vector	Description	Error Code
0	Divide error	No
1	Debug exception	No
2	NMI interrupt	No
3	Breakpoint	No
4	Overflow	No
5	Bounds check	No
6	Invalid opcode	No
7	Device not available	No
8	Double fault	Yes, 0
10	Invalid TSS	Yes
11	Segment not present	Yes
12	Stack fault	Yes
13	General protection	Yes
14	Page fault	Yes (special format)
16	Floating-point error	No
17	Alignment check	Yes, 0
18	Machine check	Depends on CPU model
19-31	Reserved	—
32-255	Maskable interrupts	No

instructions also causes an invalid opcode exception. Opcodes D6H and F1H do not generate this exception, even though they have no designed function. They are reserved by Intel.

Vector 7: Device Not Available. Two bits in CR0 (EM and MP) are used to control when — if at all — an ESC or WAIT instruction generates this exception. On earlier 80 x 86 machines, this exception was used to indicate that there was no external floating-point coprocessor interfaced to the CPU.

Vector 8: Double Fault. When two exceptions occur in sequence (the second one detected while the first is being processed), there are some combinations that cause a double fault to be signaled. Double fault exceptions are reserved for the most severe sequences, such as a page fault (Vector 14) followed by a second page fault. Interrupts and exceptions are classified into three categories: benign interrupts and exceptions, contributory exceptions, and page faults. Table 2 shows the respective classifications by vector. Whether a double fault interrupt is generated depends on the classification of both exceptions in the sequence, as indicated by Table 3. If any other exception is signaled during processing of a double fault, the processor enters shutdown mode.

Vector 9: Reserved. This vector was previously used to signal a page fault during transfer of a 387 coprocessor operand. It is not available on the Pentium.

Vector 10: Invalid TSS. This exception is generated when a problem is detected with a new TSS during a task switch. Depending on the error, the exception may be signaled before or after the task switch.

Vector 11: Segment Not Present. This exception is generated when the present bit in the current descriptor is clear. This indicates that the segment is not in memory and must be reloaded (from the hard drive). This exception is useful for virtual memory implementation.

Vector 12: Stack Fault. A stack fault is signaled when the limit of the SS selector is reached during execution of stack-based instructions PUSH, POP, ENTER, and LEAVE. Instructions that use SS as a segment override, or that use the BP register to reference memory, will also generate a stack fault if the limit is reached. A stack fault is also generated when the present bit of a new descriptor for SS is clear.

Vector 13: General Protection. This exception is the result of many different conditions that may arise. All of the following will cause a general protection exception:

- Exceeding the segment limit with CS, DS, ES, FS, or GS.
- Reading from an execute-only code segment.
- Writing to a read-only data or code segment.
- Loading a segment register with an inappropriate segment selector (such as loading DS with an execute-only segment).
- Switching to a busy task.
- Privilege violations.
- Exceeding the instruction length limit.

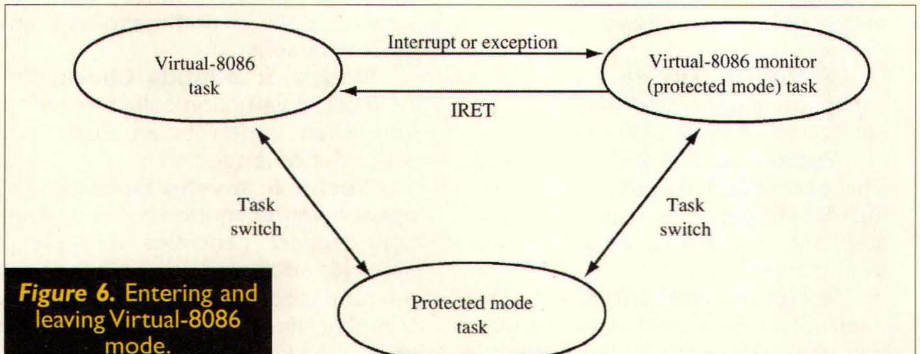

Figure 6. Entering and leaving Virtual-8086 mode.

Table 3: Generating a Double Fault

		Second Exception		
		Benign	Contributory	Page Fault
First Exception	Benign	No	No	No
	Contributory	No	Yes	No
	Page fault	No	Yes	Yes

Table 2: Interrupt/exception classifications

Class	Vector	Description
Benign interrupts and exceptions	1	Debug exceptions
	2	NMI interrupt
	3	Breakpoint
	4	Overflow
	5	Bounds check
	6	Invalid opcode
	7	Device not available
	16	Floating-point error
Contributory exceptions	0	Divide error
	10	Invalid TSS
	11	Segment not present
	12	Stack fault
	13	General protection
Page faults	14	Page fault

- Loading CR0 with improper PE/PG combination.
- Using the wrong interrupt handler when leaving virtual-8086 mode.

Windows users know that this is a bad exception to get when running a program inside Windows. Usually, Windows must be restarted to get things back to normal after a general protection exception.

Vector 14: Page Fault. A page fault exception is generated when the processor attempts to access a page that is not in memory. A page fault occurs to let the operating system know that the page must be loaded into memory. The present bit in the page directory or page table entry, when clear, indicates the page is not in memory. A page fault exception is also generated when page-level privilege is violated (the privilege is not high enough).

The Pentium pushes a 32-bit error code onto the stack of the page fault exception handler, whose meaning is described in Figure 3. The error code allows the operating system to respond to the page fault in various ways. For example, the P-bit determines whether the page must be read in from the hard disk.

Vector 16: Floating-Point Error. This exception is generated if the NE bit is set in CR0 and an FPU instruction causes an error. The handler for floating-point error may adjust the operation of the FPU accordingly (via the FPU's control word).

Vector 17: Alignment Check. This exception is generated when a memory operand larger than one byte begins at an odd address, or at an even address that is not the proper multiple of 2, 4, 8, etc. For example, a word beginning at address 1001H (must be 1000H or 1002H instead), or a double-word beginning at address 1001H, 1002H, or 1003H (1000H and 1004H are acceptable) generate this exception. To enable alignment checking, the AM bit (in CR0) must be set. Then, if the AC flag is set and the CPL is 3, alignment check will be generated.

Vector 18: Machine Check. This exception may or may not exist, depending on the model of the CPU. The CPUID instruction returns a bit that indicates the status of this exception (available, not available).

Additional Interrupt and Exception Descriptions — The remainder of the usable interrupts in Table 1 (32 through 255) are called maskable interrupts. These interrupts may be generated internally by software (via INT 32 through INT 255) or externally through an eight-bit vector number supplied with a hardware INTR request. Since the INTR signal may be masked by the interrupt enable flag, these hardware interrupts may be masked.

INPUT/OUTPUT OPERATIONS

The Pentium provides protection for input and output operations that take place in protected mode or virtual-8086 mode. When an IN or OUT instruction executes, the processor checks the task's CPL against the IOPL (Input/Output Privilege Level) bits stored in the EFLAGS register.

If the CPL is less than or equal to the IOPL, the operation is allowed. If CPL is greater than IOPL, a general protection violation exception is generated. It is important to protect I/O operations in an operating system, since many hardware features depend on proper I/O settings.

For example, an operating system might employ a counter/timer peripheral mapped to a few I/O ports that control the rate of special timing interrupts (such as a multitasking time slice interrupt). If no protection is employed, any user program may change the timer interrupt at will, causing havoc for the rest of the users.

It is better to restrict I/O operations to privileged users, and force user programs to request I/O operations from the operating system. The operating system can then decide which requests to honor to keep things running smoothly.

When the CPL is greater than the IOPL, or when the processor is operating in virtual-8086 mode (see the following section), I/O operations are allowed on a port-by-port basis via permission bits stored in the I/O permission bit map section of the task's TSS. The offset of the I/O permission bit map within the TSS is stored in the I/O map base section of the TSS.

Each byte in the bit map stores permission bits for eight consecutive ports. The sample bit map in Figure 4 indicates that access to ports 3, 7, and 12 is not allowed. Any attempt to read or write these three ports will cause a general protection violation exception. The size of the bit map may vary according to the number of ports that must be protected. Both 16- and 32-bit ports must have two or four consecutive zeros in their associated bit map positions to be allowed access.

VIRTUAL-8086 MODE

Virtual-8086 mode is the last of the three main operating modes of the Pentium processor. Virtual-8086 mode is entered from protected mode when the VM bit of the flag's register is set, and executes programs written for the 8086 (and 8088) microprocessor. Multiple virtual-8086 programs may execute simultaneously (via the multitasking capabilities of protected mode) on virtual machines.

A virtual machine comprises the hardware and software required to implement a particular task. Each virtual machine has its own 1MB addressing space and set of processor registers. The 1MB addressing space may be located anywhere in memory through the use of the Pentium's paging mechanism. The processor registers are maintained through their respective entries in the virtual task's TSS.

As in real mode, register sizes default to 16 bits. Override prefixes may be used to allow 32-bit registers and addressing modes, with the usual restrictions. Figure 5 illustrates the concept of virtual machines running on the Pentium.

Address generation in virtual-8086 mode is like that of real mode. A 16-bit segment register is shifted four bits to the left and added to a 16-bit offset to form the desired effective address. Unlike the 8086 processor — which wraps addresses around the end of a segment from FFFFH to 0000H — a virtual-8086 task retains the carryout of the 20-bit effective address, and thus accesses a larger real-mode addressing space using 21-bit addresses.

The actual range is from 000000H to 10FFEFH (FFFF0H plus FFFFH). These 21 bits are part of the 32-bit linear address used within the virtual-8086 task, and may be translated/paged to any physical address in the 4GB range of system

Continued on Page 86

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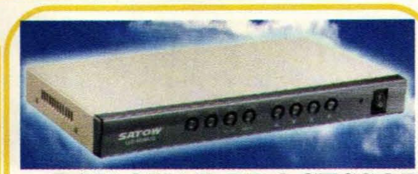

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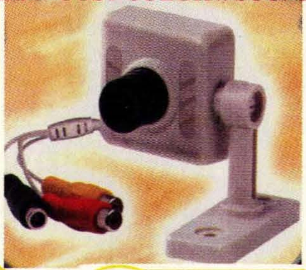

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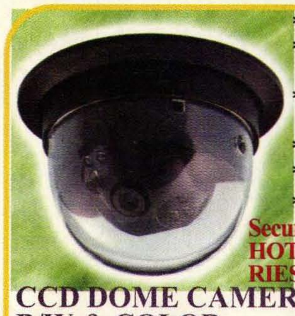

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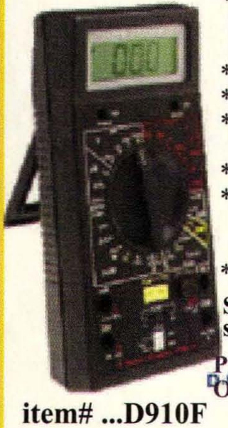

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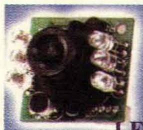

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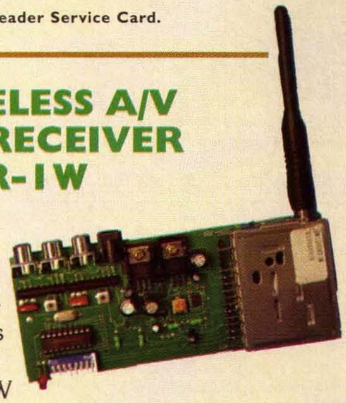

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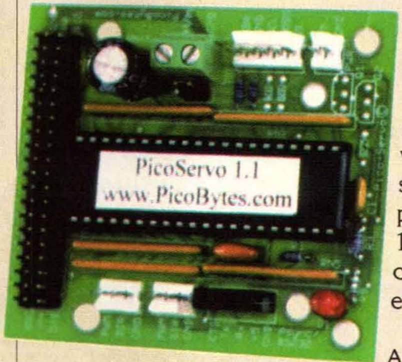

PicoBytes, Inc., announces their new PicoServo. PicoServo can control 20 hobby servos with 16-bit resolution and speed ramping, two independent PWM drivers with 10-bit resolution that can control two H-Bridge drivers directly.

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PicoServo is supplied with a comprehensive manual and source code of a sample application written in Visual Basic that demonstrates how easy it is to write programs on the PC. Controlling PicoServo is as easy as sending serial commands. Example codes are provided for BASIC Stamp® type microcontrollers.

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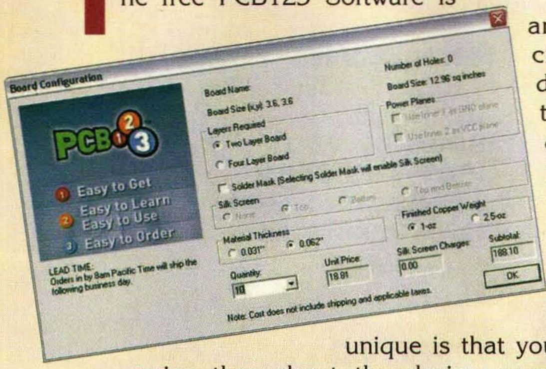

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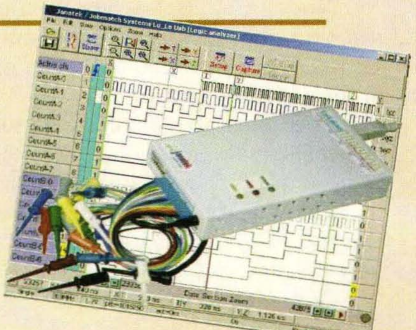

This instrument is a must for every hobbyist working with microprocessors.

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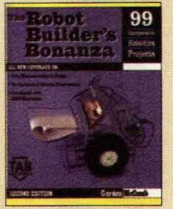

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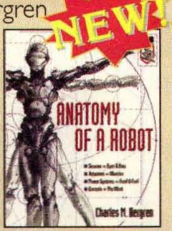

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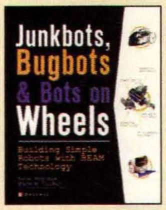

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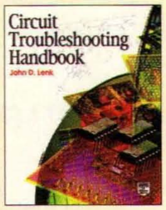

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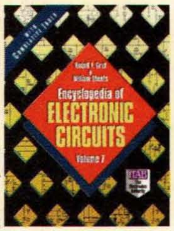

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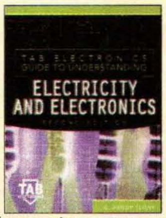

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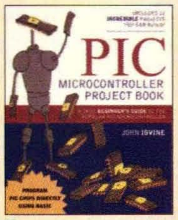

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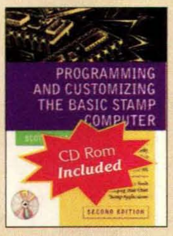

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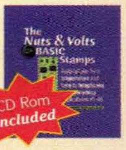

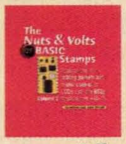

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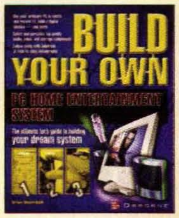

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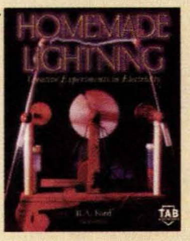

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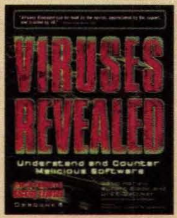

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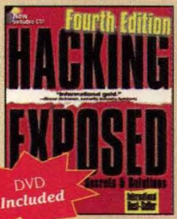

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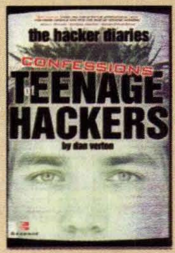

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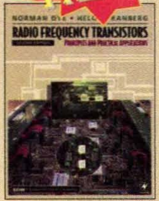

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Television Stereo Audio Hearing Wonder

If you have a hearing problem, build this handy device ... it will give you a whole new outlook on life!

This Month's Projects

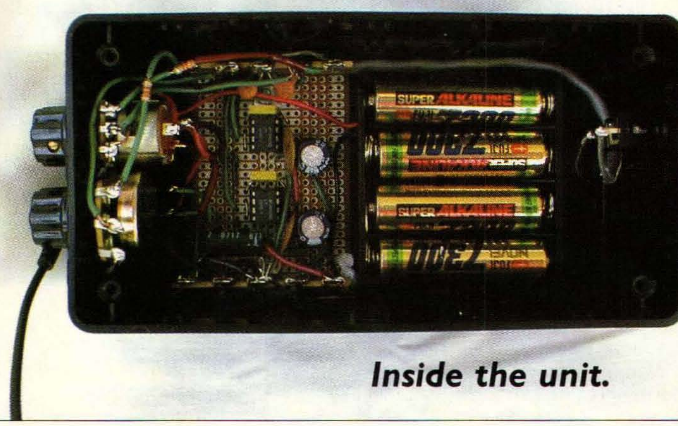
The Fuzzball Rating System

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!



Inside the unit.

For people with hearing problems, every other word can sound like mush, and too often does. Hearing Aids help, but just don't always work well when you're trying to discriminate between similar sounding words coming from your TV set. This inability can easily lead to loneliness and depression.

Finally, there is a wonderful solution. When my first version of the Hearing Wonder was published in the October 1999 issue of *Electronics Now* magazine, I received email with accolades from all over the world. Without question, it cured the problem for hundreds, maybe thousands of "hard of hearing" folks. No longer does one only hear half the story. With the Hearing Wonder, you'll hear and understand every word being said!

Now I have a Stereo version, which is even more enjoyable than the original monaural version. Not only does it give you the pleasure of full stereo, but it allows you to set the volume for each ear as you need it.

Why it Works

The reason the "Television Stereo Hearing Wonder" works so well is because each channel produces an amplification curve that is approximately equal to, and opposite to, the typical hearing loss curve. In this way, the critical high frequencies necessary to discriminate sounds are restored. Even the best and most expensive hearing aids don't seem to produce the clear, rich sounding audio that our Hearing Wonder is capable of. If you have lost the enjoyment of watching movies, sports, or news because of hearing problems, then this unit is a "must have" for you!

Over the past few years, I've built many of these amplifiers and have given many away to my hard-of-hearing friends. Almost everyone who has one wouldn't part with it for any cost, because it brings them so much enjoyment. I feel the same way and because I want to share this prize with others. Let me tell you about my Stereo Wonder.

The one drawback, however, is the fact that this amplifier must connect directly to your TV set or VCR. Check both your TV set and your VCR. If you have either a headphone jack, or an RCA-type Phono Jack labeled "Audio Out" or "Audio to Hi-Fi," then you are in luck!

Many VCRs have Audio output jacks to play back to another VCR, and this can also be used for the Hearing Wonder. Using the jacks on the TV is better, though, because if you use the VCR, it must be switched on and tuned to the program you wish to hear.

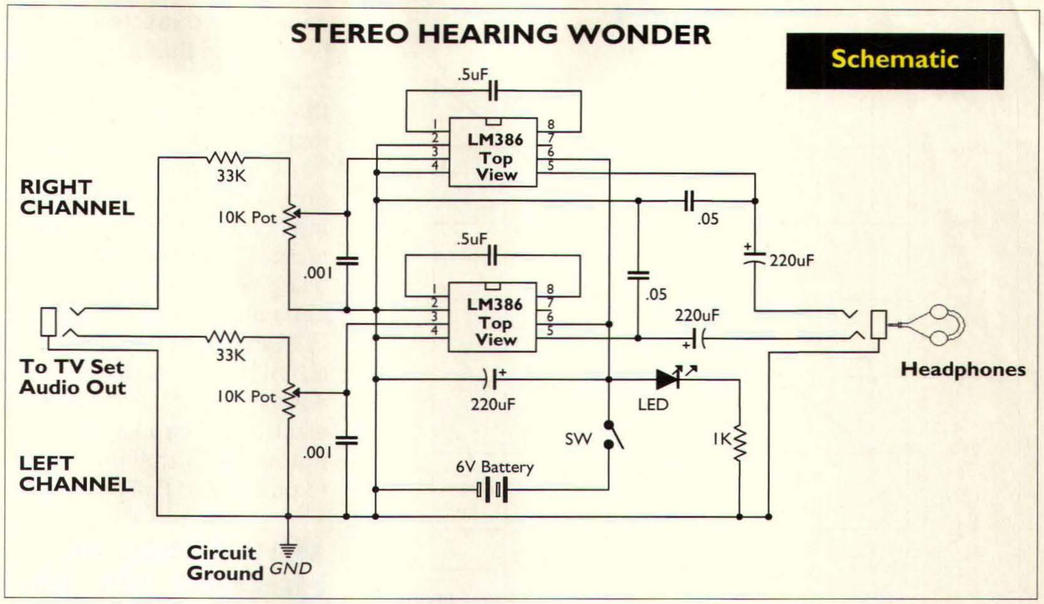
A third method is to connect the Audio Wonder to your TV's loudspeakers through an isolation transformer (this is explained later). If you don't have output jacks on your TV or VCR and you don't want to connect to your TV's loudspeaker, then go buy a new one. This "Hearing Wonder" is worth it!

The circuit is easy to build and the parts are available at local dealers for about $45.00.

This is a plot of the change in amplification gain versus a change in frequency input for the Hearing Wonder. How loud the unit sounds in the headphones depends on the volume control setting.

The area of critical speech understanding falls between 500 Hz and 6,000 Hz, and most hearing tests are conducted in this range. Persons with moderate hearing loss typically

There are no special skills needed to build the Stereo Hearing Wonder. Nothing is critical as long as there are no wiring errors made.



have frequency response degradation of 10 dB to 30 dB over this range, so our gain of about 20 dB offsets this problem nicely.

Building the Hearing Wonder

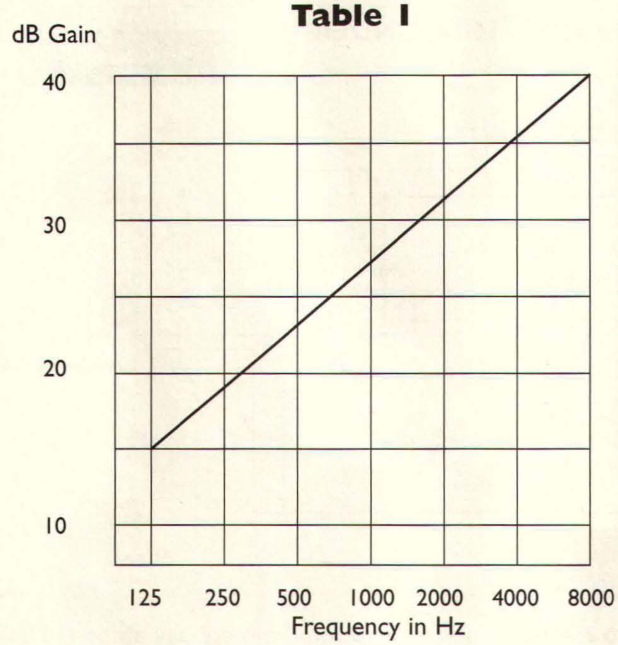
Here are some construction guidelines. I used a 6-inch L x 3-inch W x 2-inch H molded plastic enclosure to house the Hearing Wonder. Four holes should be drilled at one end to mount the two Volume controls, LED, and the Headphone jack. This requires drilling three 5/16-inch holes and one 1/4-inch hole. Drill another 1/4-inch hole at the other end for the Stereo input jack. Look at the picture of the interior view before drilling. Start with small holes and work your way up because this plastic is very soft and easily damaged. Also, make sure everything will fit well first.

I used a RadioShack #276-150 multipurpose PC board for the chassis and platform for the components. You will probably need to cut about 3/32-inch off each end to get it to fit in the enclosure. I also mounted a five-lug tie point at each end of the board to give me an easy way to connect the external wires to the controls and jacks in the Hearing Wonder.

Layout doesn't seem to be critical. Simply mount the two eight-pin sockets, spacing them equally along the center line of the PC board printed circuitry. Next, arrange the balance of the parts so they'll fit neatly on the board. The schematic calls for three 220 µF capacitors. These can actually be any value from 220 µF to 470 µF, and any working voltage up to 100 VDC. I prefer to use 220 µF — 16 VDC units because their small size makes for easy mounting. Wire the unit as shown in the schematic. The construction is straightforward and should be fairly easy with the help of the diagram and pictures.

Wire and solder all the connections, including the volume controls and switch, before mounting anything in the plastic enclosure. Note that one of the Volume controls has a single pole double throw switch mounted on it. Use your ohmmeter to make sure you connect to the two lugs that show continuity when the switch is on. Observe the polarity for the three 220 µF capacitors as shown on the

Table I



schematic. The two leads on the red LED are a different length. Be sure to connect the longer lead to the +6 volt connection.

Use a piece of shielded wire for the connection from the stereo input jack to the tie point connection of the 33K ohm resistors. Looking down on the IC sockets, orient the LM386 amplifier ICs and plug them in so the dot on the ICs is aligned with the socket end designated for pin 1.

Place the circuit board along with its connected volume control and jacks into the molded enclosure. Place washers on each volume control to make it level with the inside box ridges and mount it, the LED, and the jacks in place. Both the PC board and the battery holder are held in place using pieces of double-sided foam tape.

How it Works

The secret of the Hearing Wonder lies in the .5 µF capacitor connected between IC pins 1 and 8. This value is critical in that it must be within the range of .44 µF and 1 µF. The purpose is to introduce negative feedback that increases amplification as the input frequency increases.

Outside the unit.

Over a period of many months, I have experimented and documented many feedback configurations, including T-Pad filters, to achieve a design that would offset typical hearing losses. Ultimately, I found that simply using a .47 µF or .5 µF capacitor worked best. A 1 µF capacitor will also work well with a five dB degradation in high frequency amplification. Note too that ceramic, tantalum, or electrolytic capacitors all seem to work equally well in the circuit. You may also use two 1 µF electrolytic capacitors in series for .5 µF. Polarity does not seem to make any difference on how they connect to pins 1 and 8. The measured results appear in Table 1.

Why Some of us Need the Hearing Wonder

Persons who are "hard-of-hearing" usually have no problem hearing conversation. They simply have trouble understanding what was said. For this reason, they often ask you to repeat a word or sentence.

As we grow older, many of us lose our ability to hear the higher frequencies that help us to discriminate between words. The "Television Hearing Wonder" works well because it produces an amplification curve that is opposite from that of the hearing loss curve.

Using the Audio Wonder

This amplifier is very sensitive, and a few folks who live near radio stations might experience radio interference, although the .001 µF capacitor from pin #3 on each IC socket to ground generally eliminates this problem. If you cannot correct it in any other way, the unit may have to be put in a metal box instead of the molded plastic one.

A stereo headphone extension cable is suggested in the Parts List to connect between the TV set and your Audio Wonder. The better choice is to route a two or four conductor shielded cable under your carpet, under the floor, or overhead. Almost any pair of headphones will work. If you don't already have a pair, most electronic stores have many good types to choose from. I personally like the light-weight types.

Most TVs with stereo sound output will have two RCA-type output jacks marked Left and Right channel Output. On most TVs, these jacks are wired to connect to an external Hi-Fi amplifier. Volume is controlled by the remote control volume buttons and the volume level on the Hearing Wonder must be readjusted every time the TV's volume is changed.

Some TV sets have additional audio output jacks provided for recording. These jacks have constant fixed output regardless of where the TV's volume control is set. Plugging the Hearing Wonder into this output jack will give you the advantage of controlling the volume sepa-

TV Audio Hearing Wonder Parts List

RadioShack part numbers are shown.

1 - Molded enclosure, 6 x 3 x 2" #270-1805
1 - Multipurpose PC board #276-150
2 - Panel mount phone jacks, 1/8 in, 3 term #274-249
2 - Eight-pin solder-type DIP IC sockets #276-1995
2 - Five-lug tie point, terminal strips #274-688
1 - Battery holder #270-391
2 - Volume control knob #274-415

2 - LM386 amplifier ICs #276-1731
1 - Red LED with snap-in holder #276-018
1 - 10K ohm audio potentiometer with switch #271-215
1 - 10K ohm audio potentiometer #271-1721
1 - 1000 ohm, 1/4 watt resistor #271-1321
1 - 33K ohm, 1/4 watt resistor #271-1341

2 - .001 mF disc ceramic capacitor #272-126
2 - .047 mF disc ceramic capacitor #272-134
2 - .5 mF capacitors, see text
3 - 220 mF, 16V electrolytic capacitor #272-956

4 - "AA" Alkaline batteries #23-873

Misc.: Stereo headphones, hook-up wire, solder, and foam tape.

Cable needs depend on your personal needs. Consider using a three-foot cable with a 1/8-inch stereo plug on one end and two (RCA) phono plugs on the other to connect to your TV (# 42-2481). Use a stereo headphone extension cord for additional cable length.

rately from the TV. Turn the TV's volume down to listen in private without disturbing others.

If you have a stereo headphone jack on your TV and no output jacks, simply plug in a stereo cable with a 1/8-inch stereo plug on each end. Plug the other end into the Audio Wonder. If you do not have any audio output jacks on your TV set, it may be possible to connect the Hearing Wonder to the speakers through isolation transformers such as RadioShack #273-1380. Connect the eight-ohm secondary winding to the speaker and the 1,000-ohm winding to the Audio Wonder input.

Both the schematic and Parts List specify four AA batteries to produce the required six volts. These will last from four to eight months in normal use if you don't forget to turn the unit off.

A smaller unit can be constructed using a nine-volt battery that will last from two to three months in normal use. Simply replace the 1,000-ohm resistor connected to the LED with a 4,700-ohm resistor because of the higher battery voltage. I have constructed many units using a nine-volt battery, but prefer the six-volt unit because of the longer battery life.

I consider this article one of my greater contributions to improving the quality of life and I hope you'll build it for someone who has a hearing problem. I am also interested in hearing from anyone who builds it and I can be contacted through *Nuts & Volts* or at my email address: **raygreen@juno.com**. Build the Hearing Wonder if you have a hearing problem and it will give you a whole new outlook on life! **NV**

..e Cat Feeder Part 2

Leave Your Cats at Home With No Worries!

Last month, I described the construction of a cat feeder intended to feed a couple of cats for up to eight days. The article explained how a food box could be built from plastic extrusion and designed to be attached vertically to a wall. The box was divided into eight compartments by horizontal doors which could be released at regular times by pulses from a Drive Unit whose circuit and function were also explained. This month, I want to introduce the somewhat unusual power supply necessary to drive the design and to complete the article by describing the remaining mechanical construction.

We have reached the stage where we have to consider exactly how the doors of the feeder are normally held closed, but can be opened on cue as required. When I began working on this design, I first looked at a number of mechanical systems using door latches, springs, and solenoids, but besides the high cost of eight sets of each, I found that the cams and bearings needed to release the doors had to be cut, shaped, and positioned with some precision. Electromagnets held to small pieces of soft iron attached to the surface of each door seemed a simpler idea, but this appeared to have three serious drawbacks.

First, to keep a door closed, current had to flow continuously through the electromagnet until the moment when the door was to be released.

Consequently, the total current needed initially to hold all eight doors closed was far too high for battery back-up, which was to be included in the design against the possibility of mains failure. Second, the easiest way to recharge the feeder with food was when it was disconnected from the drive unit. Of course, with no power connection to the feeder, the doors would not stay shut. Third, I could not immediately find suitable small electromagnets anywhere at any price!

I tackled the third problem first. Relays use electromagnets and their coils are usually easy to liberate from the relay's shell. Suitable miniature types can frequently be found at a very good price on the "surplus-to-requirements" market, as well as being obtainable directly from the usual suppliers. When selecting relays, check that the liberated coil will be no more than about 3/4 inches in length, is intended for five or six volts, and has a resistance of 50 to 60 ohms. Once eight coils have been removed from their cases, any relay contacts and the whole of the metal strip used to hold the coil in place should be cut away completely. (See Photo 1). All necessary saw cuts need to be made with some care to ensure that no damage is done to the winding on the coil.

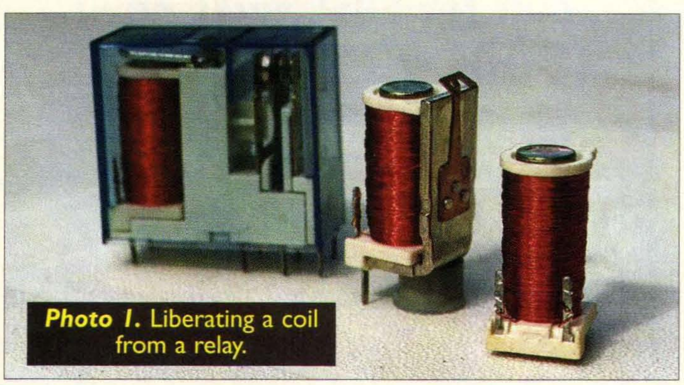


Photo 1. Liberating a coil from a relay.

Solutions to the other problems followed. It occurred to me that if instead of just a small piece of soft iron, a permanent magnet was used in the surface of each door, it would stay shut without power to the electromagnet because the permanent magnet would hold to the iron core of the coil.

Then, if a current-pulse through the coil could produce a reverse magnetic field strong enough to oppose the permanent magnet, the like poles created would repel and the door would open.

After considerable experimentation, I found I could make it do just that! However, to produce a large enough reverse magnetic field, I needed to use a low voltage relay coil, but apply a much higher voltage. In fact, I found that 25 volts were necessary to produce a large enough field to release the doors. Now I know that applying 25 volts to a six-volt coil sounds like poor practice, but it really is not. This voltage will make the coil pretty warm, but not hot enough to burn out even if connected indefinitely. However, in this cat-feeder application, the burst of 25 volts lasts for about a quarter of a second and produces no damage nor discernible increase in temperature.

So this solved both the other problems — no current is wasted in just keeping the doors closed, and they are held firmly shut without applied power while the feeder is disconnected and being recharged with food.

The prepared relay coils can now be fixed into the feeder. Remove the right side panel from the box and mark horizontal lines across the inside face, drawing the first three inches down from the top, the second 3-3/8 inches down from that, the third 3-3/8 inches down from that, and so on until eight lines have been drawn. Also draw one vertical line to divide the same face in half. The eight relay coils should be putty-glued to this surface — each on the center line and with the protruding end of its soft iron core level with a horizontal line.

Drill small holes through the panel close to where the coils are glued so that two connecting wires for each coil can be brought to the outside of the box. Then reattach this panel and check that each door will be held closed by its magnet. It is also worth using a bench power supply to apply a brief 25-volt pulse to each coil in turn to confirm that this will release its door.

If the first trial fails to open the door, connect the supply the other way around, but also note that if the magnets have been correctly fitted, every door should be released with its coil connected to the supply with the same polarity. Almost any kind of mains transformer having a secondary output of around 15-volts AC at about one amp can be used. This output is full-wave rectified by the bridge, and then smoothed by C15. C16 largely eliminates any high-frequency ripple on the output of the 7815 voltage regulator.

As I mentioned above, quite early on in my thinking it had occurred to me what a disaster it would be if the mains supply was off at a time when a door of the feeder ought to have opened. That one blocked door would prevent any more food from being dispensed. If mains failure occurred early in a vacation period, the cats would really suffer. Consequently, proper battery back-up had to be incorporated into the circuit and be designed to provide sufficient power to run the whole system for at least a few hours. Diode D9 ensures that when there is no mains power, the battery cannot discharge back into the 7815. R21 provides a trickle charging path for the battery while D10 ensures a direct route to the circuit when the battery is meeting all the power requirements. Incidentally, it must be pointed out that in this circuit, the battery may not be an optional extra.

Even with mains available, the doors may not function reliably unless the potential capacity of the battery is there to smooth out the relatively large current demand which occurs when a door-opening is triggered.

The remainder of the power supply circuit is a DC-to-DC switching converter based on an LM2577-ADJ or a LT1171C integrated circuit. D11 must be a Schottky diode and the 100uH inductor L1 must be able to carry a current of at least 750mA. VR1 allows the output voltage to be set to the minimum, which will reliably open the feeder doors. Capacitors C17, C18, and C20 smooth and de-couple the high frequencies associated with switching circuits, while C19 ensures a soft start recovery to the supply, following a door opening event.

Looking back at the driver circuit, it can be seen that the progressive ring outputs from IC7 are differentiated in turn by their C/R pair to produce a brief pulse which momentarily operates the corresponding transistor-switch in the ULN2804.

All the door coils are commoned to the 25-volt supply and have their other contacts switched low in turn via the open-collector outputs of the integral transistors in IC8. This useful driver IC will switch up to 500mA per channel (600mA intermittently), and each switch is protected internally by a diode across its output which eliminates the back EMF that occurs when inductive components like coils are switched off.

Pressing switch S3 allows IC7 to be reset when it is at any point in its counting cycle, resulting in its first output (pin 3) going high. A feedback link from this pin to pin 9 on the display allows the second decimal point to light whenever IC7 is reset.

This will occur when the feeder has just delivered its last meal or after pressing S3 — should you need to top up the feeder with food when it is only partially empty. A lit decimal point in the display gives the comforting assurance that the next feeder door to open will be the lowest.

The printed circuit board design includes some additional capacitors — numbered from C21 to C26 — which do not appear on the circuit diagrams, but are necessary to decouple the power lines at appropriate points on the board. These are included in the parts list at the end of this article.

MAKING UP THE PCB

The PCB is small and working on it will need patience, a steady hand, and a cool soldering iron. If you wish to make your own board, you can download a full-size pattern from the

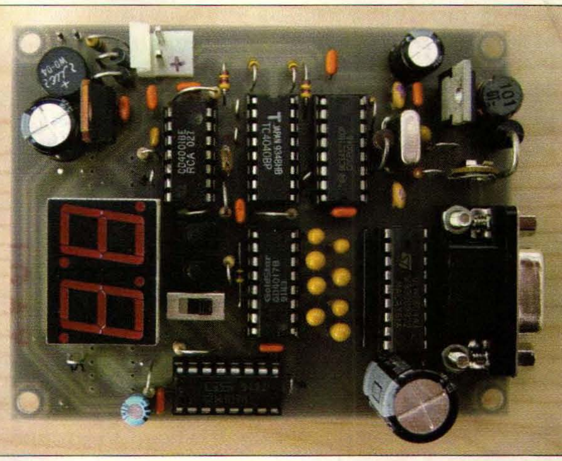


Photo 2. Component side of the PCB.

Nuts & Volts website at **www.nutsvolts.com**. Figure 2 shows a birds' eye view of the tracks and the copper fill necessary to complete all connections including ground fill, while Figure 3 shows the PCB layout of component placement. An enlarged view of Figure 3 can also be downloaded from the *Nuts & Volts* website.

In spite of the relative complexity of the circuit, only one link (TP5) needs to be fitted, and even that is intended to be a test point, and so it must be joined by an inverted U of bare wire anyway.

For the less experienced constructor, it is probably easier to build this project in segments, checking each section before moving on to the next. To carry out full tests, an oscilloscope and a variable squarewave function generator are required, but many checks can be made using only a normal multimeter.

Construction should commence with the 12 -15 volt power supply, starting with the soldering in of all the components of Figure 1 as far across the drawing to the right as D10. IC9 is a tall component and will stand well clear of the board. Consequently, this and all other tall components should be seated into their holes as far as possible.

For the initial test, the battery does not need to be fitted, but having completed the first part of the power supply, temporarily attach the secondary of the 15-volt AC transformer and check that the DC voltage out of D9 is about 14-1/2 volts. Disconnect the transformer.

Most of the integrated circuits in this project are of CMOS construction and, consequently, they are static-sensitive. Handle them as little as possible, while always trying to avoid touching the pins.

Next, work on the clock section. IC1, IC2, and IC3 should eventually be fitted into sockets, so for now, solder

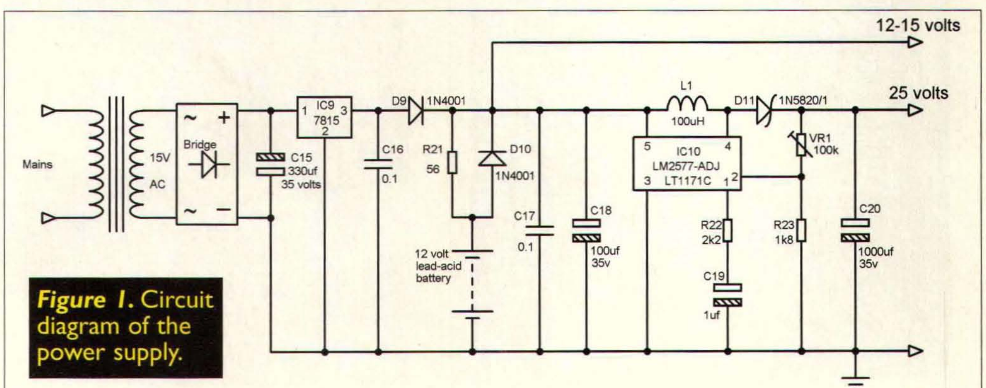


Figure 1. Circuit diagram of the power supply.

in their two 16-pin sockets and one 14-pin socket, together with all their associated components (including S1 and R7). Then add the loops of wire for the four test points — TP1 to TP4. Reconnect the transformer and check that the three IC sockets are carrying the correct voltage at their power pins. To save time later, also check the power and ground pads for all the other dual-in-line ICs. Disconnect the transformer and plug in just IC3 (4001) before reconnecting the transformer.

Check that the outputs at both TP3 and TP4 are the same, that is, normally low but going high every time S1 is closed. Power down the board, plug in IC2 (4040), and then power up again. The output at TP2 will normally be one pulse each hour and directly testing for that would require a lot of patience! However, if you use a frequency generator to directly input into TP1, a squarewave of 3,600Hz at about 12 volts referenced to ground, the output at TP2 should be that input frequency divided by 3,600, or one pulse per second. This signal can be confirmed on an oscilloscope or seen on a multimeter.

Disconnect the frequency generator and the transformer. Plug in IC1 (4521) and reconnect the transformer. Check that the output at TP1 is one pulse per second. If all is well with these tests, the clock circuits are all functioning correctly. Disconnect the transformer.

The next piece of construction requires concentration and patience. Turn the PCB over and, just by resting the pins on their correct pads, place a 16-pin socket into position for IC4. Then solder the pads and pins of a pair of opposite corners of this socket followed by all the others. Repeat this procedure for the socket, which will hold IC5. It is now worth spending a little time checking the continuity of all pads with their associated pins, as well as determining that none are shorted to a neighbor, or incorrectly to the ground fill. (Don't forget that some of them are intended to be grounded!)

Return to the component side of the board and fit a wire loop for TP5. Solder in components R8 and C5.

Turn the board over and continue on the copper side by soldering in the diodes, D5, D6, and D7, followed by the one-watt resistors R9 and R10.

An 18-pin socket for the recommended dual display is probably not commercially available, but can easily be made by cutting off the six unwanted pins at the end of a standard 24-pin socket, leaving nine pins on each side. The cut-down socket is plugged into place from the component side of the PCB and soldered in.

By now, this area is a bit congested, so have a good look around to see that all the soldering is sound and there are no solder splashes shorting tracks with each other or to ground fill. If all looks satisfactory, very carefully plug in IC4 and IC5 (both 4026), ensuring that they are seated the correct way and that no socket pins are squashed. Then fit the display. Reconnect the transformer and a random number should be displayed. Pressing S1 should increment that number.

Eventually, a count of 23 should immediately advance to 00. If all is well and you have the patience now to leave the unit running, sometime between 15 and 35 minutes later, the display should independently increment by one via the pulse coming from the clock circuits rather than by operating S1. But if construction is to continue straightaway, disconnect the transformer.

Two 16-pin sockets should now be soldered in to accommodate IC6 and IC7. Also fit S2 and S3, resistors R11 and R12, capacitor C6, and a wire loop for TP6 and diode D8. Plug in IC6 and IC7 (both 4017). Leave S2 switched to its lower (open) position and reconnect the transformer. As well as some random number, the decimal point on the display may now be lit. If it is not, press S3, it should light.

Now use S1 to advance the clock to 06 or 16, whichever comes first. On the next press of S1, the output at TP6 should go high and the decimal point extinguish. Relight it by pressing S3 and, via S1, advance the display by one. The output at TP6 should go low. Continue pulsing S1 to a 16 or 06 display and check that the next increment of the clock will extinguish the decimal point again. Relight the decimal point by pressing S3 and switch S2 to its upper (on) position. Increment the clock using S1 and check that the decimal point is extinguished on the 06 to 07 transition, but not on 16 to 17. Return S2 to its lower position and disconnect the transformer. Now the 18-pin socket for IC8 and the rest of the components can be soldered in. Fit IC8 (ULN2804).

The eight outputs to the feeder box can be terminated on the PCB by a standard, right-angled nine-pin, D-type socket with a corresponding socket wired to the eight relay coils on the feeder box. The connections to the feeder socket must allow for the

Figure 2. PCB as seen from the component side (*not to scale*).

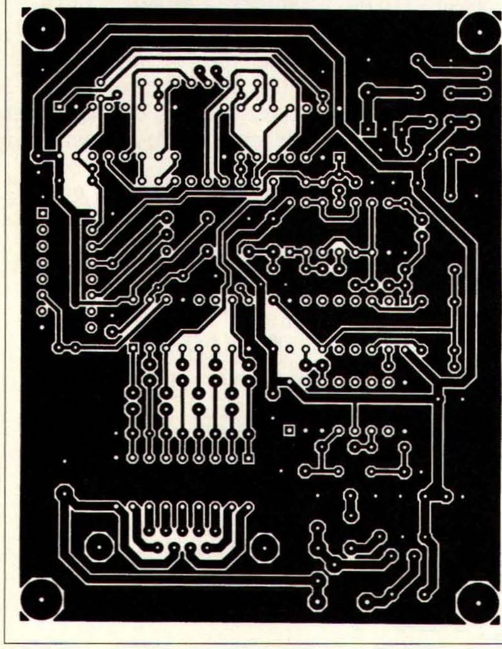
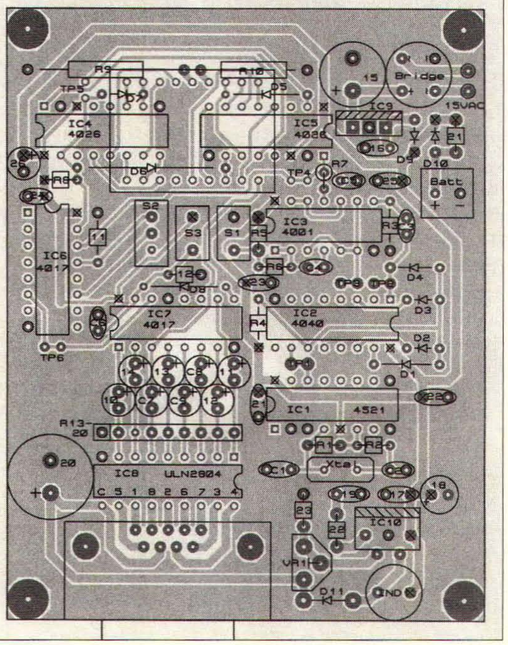


Figure 3. PCB layout to aid correct placement of components (*not to scale*).



order in which the signals from the PCB are dispatched. This order is printed on the output side of IC8 in Figure 3 — one side of the top door coil must ultimately connect to IC8, pin 13, the coil of the next door down with pin 16, the next with pin 15, and so on. All the other corresponding contacts of the coils must be commoned to IC8, pin 10. A standard nine-way computer serial cable can be used to connect together the PCB and feeder box.

Now the final tests can be made. Reconnect the transformer and check the voltage at the cathode of D11. VR1 should be adjusted to make this 25 volts. Connect a charged 12-volt lead-acid gel battery to its socket on the PCB. Disconnect the AC supply and check that the clock display remains unchanged — apart from a very slight reduction in brightness. Reconnect the AC supply. If necessary, press S3 to light the decimal point. Stand the feeder box vertically and close all the doors. Connect the feeder to the PCB by the nine-way computer cable.

Use S1 to increment the display. On the 06 to 07 (or 16 to 17) transition, the lowest door should open and the decimal point extinguish. Continuing to pulse S1 should, at the same transitions, open all the doors in turn from the bottom upwards. When the top door opens, the decimal point should light again. In normal use, this would be the signal to refill the feeder, but in addition, it stands as confirmation that the next door to open will be the lowest.

If the doors fail to open reliably, the voltage at the cathode of D11 can be tweaked up to as high as 30 volts and even a little further (but it should be left at the minimum which will always operate all the doors). There is about a two-volt drop across each switch in IC8 as it operates so, providing the resistance of each coil is about 55 ohms, the momentary current flow being switched does not exceed the limits of the ULN2804. Perhaps more importantly, these dry tests do not take into consideration the weight of the food in each feeder compartment. Experiments with these full will almost certainly result in a much smaller voltage than 25 being necessary.

As a final test, ensure that with the AC supply off, the feeder doors still function with only the battery providing power. When the feeder is not in use, the battery should be disconnected from the PCB so that the display does not drain it to a point where it can no longer be recharged.

The drive unit is finished off with a suitable case to enclose the PCB, battery, and transformer. A small rectangular window should be cut in the case so that the three switches can be accessed and the display seen.

The only remaining construction work to be done is closing off the front face of the feeder box using our previously cut piece of Plexiglass. In order to fill the feeder with food, this cover must be easy to remove and replace, but needs to be immovable (from the cat's point of view) when fitted. I used two 28-inch lengths of thin 3/4-inch angle plastic and cut (with scissors!) one face of each to be 3/8-inch wide.

With the feeder box horizontal, the Plexiglass was placed in position and small screws were used to screw the 3/4-inch sections of the angle-plastic onto each side face of the feeder, leaving the panel trapped top to bottom by the 3/8-inch faces. Consequently, when the feeder needs filling, the front panel can be slid out vertically from its side glides, but is securely held in place when the feeder is in use.

USING THE FEEDER

Once the correct hour has been set, the Reset button used to light the decimal point, the feeder filled with food, and the box positioned on a convenient wall, you can be on your way to that well-deserved vacation. However, there is one operating quirk which needs mentioning. Whenever the feeder box and drive unit are connected, operating the Reset button will always open the top door if it is closed. You can always recharge empty compartments with food while others are still full, but now you will need to reset the system with the Reset button, and should do so before the feeder and drive unit are reconnected with the serial cable.

It has been over 18 months now since I completed my cat feeder. As I explained at the beginning, my purpose in making it was to give us the opportunity to go away for a long weekend (or even week!) without having to inconvenience someone else with feeding our cats.

However, we made a discovery during the early experimental days when the feeder was under test, but we were actually at home. The cats quickly got used to getting their food from the feeder and not from us, and consequently, they stopped bothering us at those times when we would otherwise have fed them ourselves. We now use our feeder all the time, whether we are away or not. Every four days the feeder is empty and after disconnecting the nine-way cable, the box is lifted from its retaining screws in the wall, placed on its back, the front panel slid out and any residual bits of food which might have got trapped are cleared away. Then all eight compartments are half-filled with food, the front panel replaced, and the feeder dropped back onto its two retaining screws. Before reattaching the cable, a check is made to ensure that the decimal point is lit and that all is ready for supplying the first of eight new meals.

The cost of materials and components for this project are about the same as boarding two cats in kennels for only a few days. Consequently, just one long week-end trip away from home and the feeder will have paid for itself!

Our cats have been wonderful friends to us, but it is nice to get away from them and the house once in a while. I hope that you will delight in making your own feeder and enjoy the freedom that using it allows. **NV**

PARTS LIST

Resistors
- R1 — 4M7
- R2,22 — 2k2
- R3,12 — 100k
- R4,8,11 — 10k
- R5 — 47k
- R6 — 120k
- R7 — 1k
- R9,10 — 220, one watt
- R13-20 — 8 x 100k, nine-pin SIL
- R21 — 56
- R23 — 1k8

- VR1 — 100k, vertical trim

Capacitors
- C1,2 — 22p
- C3,5,6 — 10n
- C4 — 15n
- C7,8,9,10,11,12,13,14 — 10uF, elect. tant
- C15 — 330uF, 35 volts, elect
- C16,17,21,22,23,24,25 — 100n
- C18 — 100uF, 35 volts, elect
- C19 — 1uF, elect. tant
- C20 — 1000uF, 35 volts, elect
- C26 — 22uF, 16 volts, elect

Integrated Circuits
- IC1 — 4521 CMOS
- IC2 — 4040 CMOS
- IC3 — 4001 CMOS
- IC4,5 — 4026 CMOS
- IC6,7 — 4017 CMOS
- IC8 — ULN2804
- IC9 — 7815 volt reg
- IC10 — LM2577-ADJ or LT1171C

IC Sockets
- 14 pin DIL — x 1
- 16 pin DIL — x 6
- 18 pin DIL — x 1
- 24 pin DIL — x 1

Diodes
- D1,2,3,4,5,6,7,8 — 1N4148
- D9,10 — 1N4001
- D11 — 1N5820 or 1N5821, Schottky
- Bridge rectifier — 100PIV, 1A
- Display — Dual, seven segments, com. cath

Crystal
- X-tal — 4.194304 MHz

Inductor
- L1 — Inductor, 100uH, 750mA

Switches
- S1,3 — Press-to-make
- S2 — 1P, on/off, slide

Miscellaneous
- Transformer — 15-24 volt sec, 1amp
- Battery, sealed, lead-acid gel, 12 volt, 0.7 or 1.2 amp
- Nine-way serial cable, D-type, Male-Male
- 2 x D type, nine-way sockets Right Angled
- 8 x relays — 5 or 6 volt, 50-60 ohm coil
- Battery plug and socket Case, plastic extrusion, screws, etc.

Build an RC-Failsafe

Failsafe devices are key to safety in radio-control applications.

It was a picture perfect Saturday at the local parking lot where RC enthusiasts are frequently found enjoying their hobby. I was just a spectator on this particular day enjoying the sound and smell of fuel-burning RC-vehicles touring the tarmac. I was just about to leave when I heard a chainsaw-like sound come to life. The sound was coming from a large, 1/5 scale RC-racing vehicle that was not typically seen at this RC-hangout. A crowd quickly formed that was eager to see this 39 pound monster machine tear up the parking lot.

The vehicle was looking very good as it made several laps around the makeshift track that was put in place for the weekend. The driver started to get bored with just running the car in circles, so he started doing high-speed runs up and down the lot. The driver was truly testing the limits of the vehicle with passes in the range of 30 to 40 mph.

On the fifth drag-run, the vehicle quickly shot past the smooth part of the lot into an area that only RC-monster trucks would dare to go. The crowd silenced as it watched in disbelief, the vehicle bouncing on the ugly asphalt. The silent question for the driver on everyone's mind quickly became heard "What are you doing?" The driver answered with a look of horror on his face, "I have lost control!" A three-foot deep drainage ditch finally stopped the vehicle. The model was recovered with extensive damage. A witness to the carnage asked the driver, "Did you test your failsafe?" The response was, "What is a failsafe?"

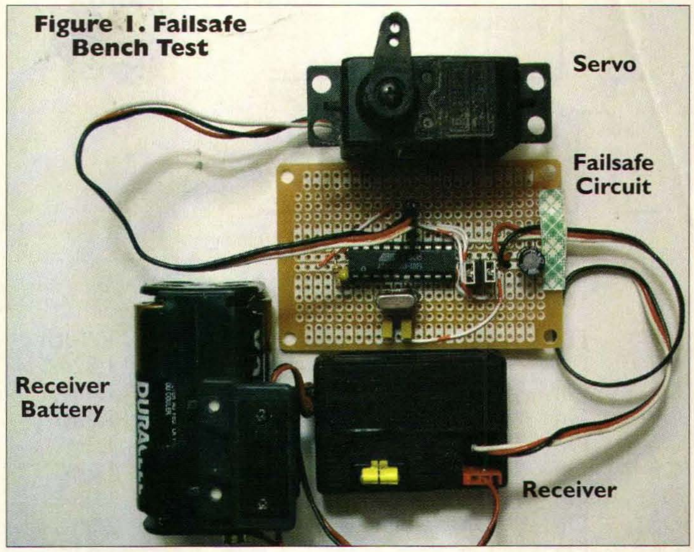
After listening to the more experienced modeler explain what a failsafe was, I decided to build my own.

DESCRIPTION

Failsafe devices for radio-control applications are used to help prevent a runaway model that could severely injure a person or cause property damage. A responsible modeler should always do everything possible to prevent accidents. A failsafe device helps in the quest for safe modeling. The failsafe device is connected between the radio receiver and the servomotor controlling the model (Figure1). The circuit gets its power from the receiver's six-volt battery pack via the three-pin connector (J4). The servo that is to be controlled using the failsafe is connected to J3. In the event that radio signal is lost, the failsafe circuit will take control by moving the servo output arm to a predefined position. The most common application would be to use a failsafe device for the servo that controls the throttle on a fuel-burning model. If the signal is lost while the motor is running at high speed, the failsafe will return the throttle to an idle position. The risk of injury and damage is reduced at idling speeds.

The heart of the failsafe is an Atmel 2313 microcontroller running at 10MHz (Figure 1). The +6-volt power spec of the 2313 simplifies the circuit by getting its power directly from the receiver's six-volt battery pack. I used Bascom-AVR software from MCS-Electronics to program the tiny 20-pin device. Bascom-AVR is an easy-to-use BASIC compiler that is very powerful and inexpensive. The STK500 development board from Atmel was used for development/programming. The circuit was built using point-to-point wiring. The low parts count and non-critical parts placement justified the use of a perf-board assembly method.

Figure 1. Failsafe Bench Test



The failsafe circuit is designed to receive the pulse-width modulated signal from the receiver, and duplicate it on pin 15. The duplicated signal is fed to the servo connector J3. The outputted control signal on J3 closely matches the receiver input signal from J4 during signal reception. If the signal reception is lost, the failsafe circuit will output a control signal generated by the microcontroller. The circuit will also ignore pulses that are not in the proper range. Too many ignored pulses will trigger a failsafe state. The position of the servo during the failsafe function is controlled using the jumpers J0-J2. The failsafe circuit will return user control after a steady signal is received.

This circuit was designed for radio systems that use pulse-width modulated control signals. The signal from this type of system looks like Figure 2. The servo position is proportional to the width of the signal's pulse. A typical controlling pulse-width is between 1mS and 2mS with a frequency of about 50Hz. While the transmitter's joystick is in the center position, a pulse-width of about 1.5mS is observed. In the full-forward position, the pulse width is 1mS — full reverse produces a 2mS pulse. Digital servos have different control signals that will not work with this circuit.

SOFTWARE THEORY

The program starts by doing the typical initialization of

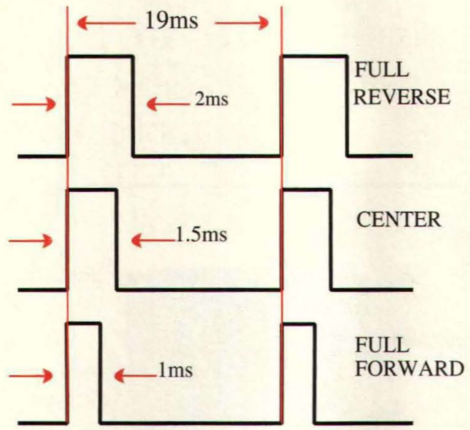


Figure 2. Servo Control Signal

Figure 3. Servo Position Table

J0	J1	J2	Position	Width
Off	Off	Off	Center	1.52mS
On	Off	Off	2/3 reverse	1.8mS
Off	On	Off	1/3 reverse	1.6mS
On	On	Off	1/3 forward	1.3mS
Off	Off	On	2/3 forward	1.2mS
On	Off	On	Full forward	1.0mS
Off	On	On	Full reverse	2.0mS
On	On	On	Center	1.52mS

peripherals and variables. Timer0 is an eight-bit timer used for missing pulse detection via the "Mispulse" overflow interrupt routine. The timer is initialized with a prescale of 1024, which provides an overflow in 32mS. The Mispulse routine performs the failsafe duties by replacing the lost radio signal. During signal reception, Pinb.3 is set as an output for driving the servo, while pind.6 accepts input from the receiver. The program is compact with only four variables needed.

The first real task the processor must do is read the jumper settings of J0-J2 and set the selected servo position. Headers J0-J2 are connected to port b.0, b.1, and b.2. A binary number between 0 and 7 is selected by installing jumpers on those pin headers. After the value of port b is stored in variable "Position," it is ANDed with a mask binary number of 00000111. The result will be just the binary input from the jumper settings stored in variable "Position." A select-case routine is entered next using the number in "Position" to choose what value "Pwm1a" will be loaded with. Figure 3 shows a truth table for what position the servo will be set to for a given jumper setting.

Pwm1a is a register that is used when timer1 is configured for PWM mode. During signal failure, the PWM from timer1 controls the servo until signal is restored. The value in Pwm1a controls the "duty cycle" (or pulse-width) of the PWM signal, while the overflow-rate sets the frequency.

After enabling timer0 interrupt and clearing its interrupt flag, the main loop of the program is entered. The main loop is responsible for duplicating the control signal from the receiver and outputting it on pin 15. Duplication is simply achieved using the routines "getpulse_3" and "getpulse_4". Getpulse_3 will wait for the control signal on pin 11 to go high and then set pin 15. Getpulse_4 will then wait for the signal to go low before clearing pin 15.

During signal duplication, the variable "Count" is incremented. Upon duplicating an input pulse, the width of the pulse will be stored in count. Each count represents 2.58uS. A count of 580 indicates a width of 1.5mS, or center position. This variable is then checked to be within a range of 350-855. A 350-855 window translates into a pulse-width range of 0.9mS-2.2mS. Bogus pulses are ignored. These routines use faster executing assembly language mnemonics for better signal duplication. Bascom-AVR recognizes most assembly lingo.

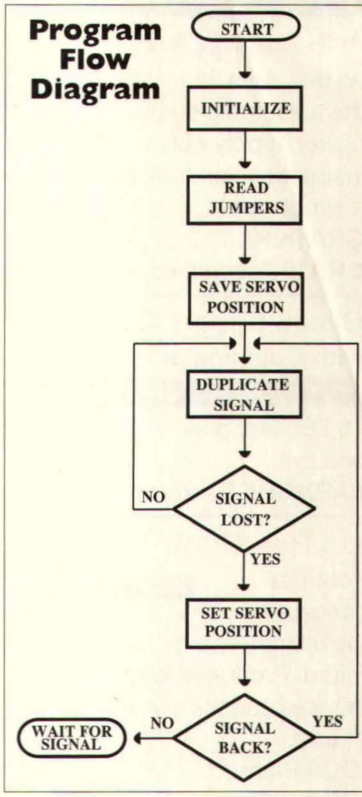
At the start of the loop, timer1 is initialized for PWM mode. The timer is configured as a 10 bit PWM with a prescale of 64. This configuration gives the PWM signal a frequency of 61Hz. The 61Hz is a little faster than the signal from the receiver, but seems to work just fine. This is

The low parts count and non-critical parts placement make this project easy for a beginner to assemble using point-to-point wiring on a protoboard. A soldering iron and basic small hand tools are all that is needed to build the circuit. The software was written in an easy-to-learn "BASIC" language. BASCOM-AVR software development suite coupled with Atmel's STK500 development board had this project's code written and debugged very quickly. The BASCOMAVR/STK500 development platform is the perfect starting place for novice microcontroller developers.

The project usage is what put the project rating at the "3" level. The builder should have a good working knowledge of RC-modeling. It is important to be very familiar with RC-equipment usage and specifications. The risk of damaging your electronic gear is minimal if you become well-educated in Radio-Controlled Guidance theory.

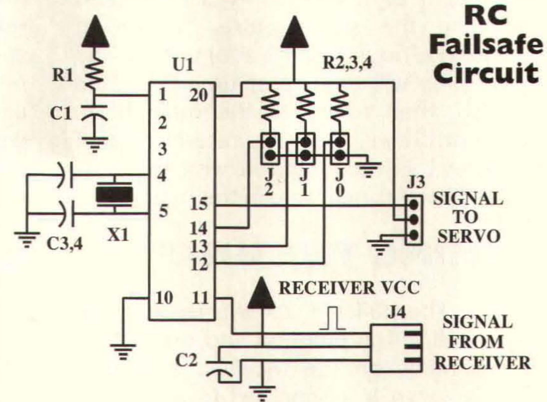
The RC-environment is very inhospitable with noise, vibration, interference, and climate as some of the challenging factors equipment designers must deal with. You as the builder and operator of the failsafe must also guard against these issues for successful implementation. This project should only be used as experimental. Commercial failsafe systems are well worth the investment, especially when personal and public safety must be protected.

Program Flow Diagram



the closest frequency that can be achieved because of the limited prescale options. The "disconnect" mnemonic in the timer set-up is needed to remove the PWM connection from pin 15 after the radio signal is restored so software can set and clear it for signal duplication.

RC Failsafe Circuit



At the end of the main loop, timer0 is set to zero. If the loop is not completed in 32mS (indicating a lost signal), the mispulse routine will be called. If the routine is called for the first time out of a cycle of two, it simply sets the D bit, then returns. If the signal is still not restored in an additional 32mS, the routine will be called a second time. The two cycle interrupt routine provides a 64mS delay before the failsafe mode is entered. The second interrupt call is realized by reading the D bit that was set during the first call. If the D bit is set when entering the routine, the failsafe mode is invoked.

The function of the failsafe is to provide a control signal that moves the protected servo to a position that was set using the jumper settings. The process starts by configuring timer1 for PWM mode and connecting it to pin 15. The mnemonic "Clear Down" in the timer1 config replaces the mnemonic "Disconnect" that was used in the first timer1 config. This change connects the PWM output to pin 15. The servo is now under the control of timer1.

The position of the servo arm will move to the location that was selected using the jumpers. A typical setting would be the center position that is selected by all three jumpers in place. The center position has a pulse-width of 1.52mS that is controlled by the pwm1a register which has the number 95 stored in it. To calculate the pulse-width for a given pwm1a value, use the following formula: 0.000008

Build an RC Failsafe

* PWM1A * 2. (Example: 0.000008 * 95 * 2 = 0.00152sec = 1.52mS.) By using different values for pwm1a, the servo position during failsafe mode can be "tuned" to the exact position for the application.

Now that the model is in autopilot, the routine will wait for the signal to be restored. The "for and next" routine will wait until five acceptable pulses from the receiver are detected before returning control to the transmitter. Signal integrity is checked using the same pulse measuring method found in the main loop. The routine will then clear timer0 and its flag, then return to the main loop. Control will not be returned until timer1 is reconfigured with the "disconnect" mnemonic in the main loop.

USING THE UNIT

The failsafe circuit is easy to install. J4 is plugged into one of the channels on the receiver, and then the servo in connected to J3. Using the jumper truth table, a servo position should be selected. The transmitter is first to be powered up, followed by the receiver. A quick test should be executed by moving the transmitter joystick to verify a full range of servo motion. Moving the joystick to a non-failsafe position, then turning off the transmitter tests the failsafe. The servo should move to the selected failsafe position. The servo should return to the position of the joystick after powering up the transmitter.

I only run surface-type RC models. I will typically use a failsafe on the servo that controls the throttle on fuel-burning models. If radio signal is lost, the servo is programmed to return to the idle position. Nitro burning cars have a clutch assembly that will allow the vehicle to stop at idle. For a gas boating application, I will install two servos: one for the throttle and one for the rudder. Boats that do not have a clutch will still move when the engine is at idle. A failsafe on the rudder could be set to steer the boat in a circle to help prevent a collision.

I have no experience with model airplanes, so I could only guess at proper failsafe usage. I would guess the throttle failsafe should not be set to idle, but should be set to maybe one-third full throttle. I would think the aircraft would just fall out of the sky at idle — no good! Setting the throttle to one-third and the control surfaces to gently spiral the craft until signal is restored, would be my guess at failsafe usage.

FINAL THOUGHTS

Even though I have had much success, I would only recommend this circuit to be used for experimental purposes. There are several commercial failsafe devices available for a reasonable price. Manufacturers spend tons of time and money in research and testing of their products. An RC environment has many design challenges that are difficult for the average designer/builder to overcome. Vibration, radio-interference, motor interference, fuel, water, static, and stress are some of the variables. I have grown to develop a great respect for talented designers and manufacturers after having attempted many times to duplicate a product or build it better. Occasionally, I do succeed at building a better mousetrap, but only at the expense of money and time.

I consider this project a success, having met four main objectives: work as designed; be useful; learn something; and have fun. The satisfaction of "doing it yourself" is something we all enjoy.

All the parts for the project can be obtained from Digi-Key (**www.digikey.com**) The STK500 development board can also be obtained from Digi-Key. The programming software (Bascom-AVR) can be found at (**www.mcselec.com**). MCS-Electronics provides a fully functional demo version (limited to 2K of code) that would be sufficient for this project. The service and products from MCS-Electronics are tops. **NV**

Alonzo Trueland can be reached at: **atrueland@mybluelight.com**.

PARTS LIST

U1	—	Atmel 2313-10 microcontroller
R1-R4	—	10K ohm resistors
C1	—	1uF capacitor
C2	—	47uF capacitor
C3,C4	—	22pF capacitors
J0-J3	—	Single row pin header
J4	—	RC-servo cable
X1	—	8MHz crystal

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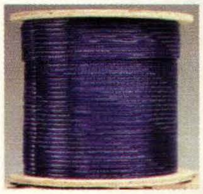

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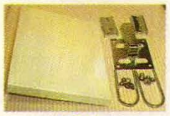

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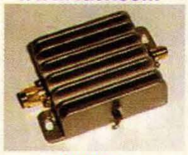

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BIPOLAR TRANSISTOR COOKBOOK — PART 1

Ray Marston explains bipolar transistor principles and describes basic circuit configurations in this opening episode of an eight-part series.

by Ray Marston

The bipolar transistor is the most important "active" circuit element used in modern electronics, and it forms the basis of most linear and digital ICs and op-amps, etc. In its discrete form, it can function as either a digital switch or as a linear amplifier, and is available in many low, medium, and high power forms. This opening episode concentrates on basic transistor theory, characteristics, and circuit configurations. The remaining seven parts of the series will present a wide range of practical bipolar transistor application circuits.

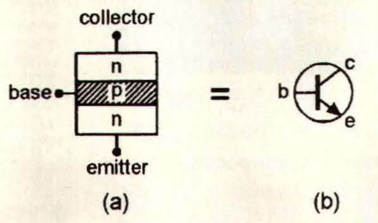


Figure 1. Basic construction (a) and symbol (b) of npn transistor.

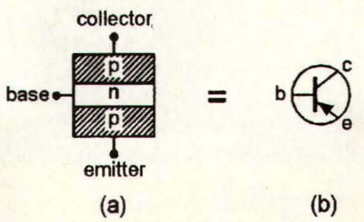


Figure 2. Basic construction (a) and symbol (b) of pnp transistor.

BIPOLAR TRANSISTOR BASICS

A bipolar transistor (first invented in 1948) is a three-terminal (base, emitter, and collector), current-amplifying device in which a small input current can control the magnitude of a much larger output current. The term "bipolar" means that the device is made from semiconductor materials in which conduction relies on both positive and negative (majority and minority) charge carriers.

A normal transistor is made from a three-layer sandwich of n-type and p-type semiconductor material, with the base or "control" terminal connected to the central layer, and the collector and emitter terminals connected to the outer layers. If it uses an n-p-n construction sandwich, as in Figure 1(a), it is known as an npn transistor and uses the standard symbol in Figure 1(b). If it uses a p-n-p structure, as in Figure 2(a), it is known as a pnp transistor and uses the symbol in Figure 2(b).

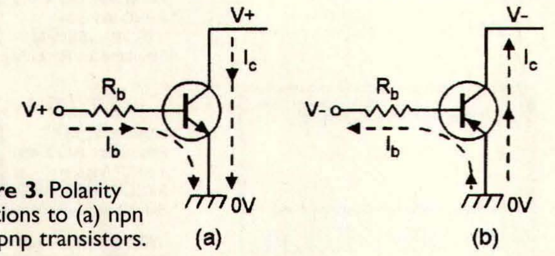
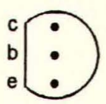


Figure 3. Polarity connections to (a) npn and (b) pnp transistors.

Parameter	2N3904	2N3906
Transistor type	npn	pnp
I_C (max)	200mA	-200mA
V_{CEO} (max)	40V	-40V
V_{CBO} (max)	60V	-40V
P_T (max)	310mW	310mW
h_{fe} (= a.c. beta)	100-300	100-300
f_T (typ) = gain/bandwidth product	300MHz	250MHz



TO-92 case

Figure 4. General characteristics and outlines of the 2N3904 and 2N3906 low-power silicon transistors.

In use, npn and pnp transistors each need a power supply of the appropriate polarity, as shown in Figure 3. An npn device needs a supply that makes the collector positive to the emitter — its output or main-terminal signal current (I_c) flows from collector to emitter, and its amplitude is controlled by an input "control" current (I_b) that flows from base to emitter via an external current-limiting resistor (R_b) and a positive bias voltage. A pnp transistor needs a negative supply — its main terminal current flows from emitter to collector, and is controlled by an emitter-to-base input current that flows to a negative bias voltage.

In the early years of bipolar transistor usage, most transistors were made from germanium semiconductor materials. Such devices had many practical disadvantages: they were fragile, excessively temperature-sensitive, electronically noisy, and had very poor power-handling capacities. Germanium transistors are now obsolete. Virtually all modern bipolar transistors are made from silicon semiconductor materials. Such devices are robust, have good power-handling capacities, are not excessively temperature sensitive, and generate negligible electronic noise.

Today, a very wide variety of excellent silicon bipolar transistor types are readily available. Figure 4 lists the basic characteristics of two typical general-purpose, low-power types — the 2N3904 (npn) and the 2N3906 (pnp) — which are each housed in a TO-92 plastic case and have the under-side pin connections shown in the diagram. Note, when reading the Figure 4 list, that $V_{CEO(max)}$ is the maximum voltage that may be applied between the collector and emitter when the base is open-circuit, and $V_{CBO(max)}$ is the maximum voltage that may be applied between the collector and base when the emitter is open-circuit. $I_{C(max)}$ is the maximum mean current that can be allowed to flow through the collector terminal of the device, and $P_{T(max)}$ is the maximum mean power that the device can dissipate, without the use of an external heatsink, at normal room temperature.

One of the most important parameters of the transistor is its forward current transfer ratio, or h_{fe} — this is the current-gain or output/input current ratio of the device (typically 100 to 300 in the two devices listed). Finally, the f_T figure indicates the available gain/bandwidth product frequency of the device, i.e., if the transistor is used in a voltage feedback configuration that provides a voltage gain of x100, the bandwidth is 1/100 of the f_T figure, but if the voltage gain is reduced to x10, the bandwidth increases to $f_T/10$, etc.

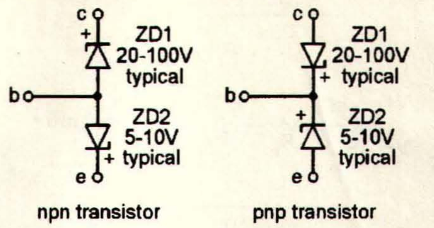
TRANSISTOR CHARACTERISTICS

To get the maximum value from a transistor, the user must understand both its static (DC) and dynamic (AC) characteristics. Figure 5 shows the static equivalent circuits of npn and pnp transistors. A zener diode is inevitably formed by each of the transistor's n-p or p-n junctions, and the transistor is thus (in static terms) equal to a pair of reverse-connected zener diodes wired between the collector and emitter terminals, with the base terminal wired to their "common" point. In most low-power, general-purpose transistors, the base-to-emitter junction has a typical zener value in the range 5V to 10V — the base-to-collector junction's typical zener value is in the range 20V to 100V.

Thus, the transistor's base-emitter junction acts like an ordinary diode when forward-biased and as a zener when reverse-biased. In silicon transistors, a forward-biased junction passes little current until the bias voltage rises to about 600mV, but beyond this value, the current increases rapidly. When forward-biased by a fixed current, the junction's forward voltage has a thermal coefficient of about $-2mV/^0C$. When the transistor is used with the emitter open-circuit, the base-to-collector junction acts like that just described, but has a greater zener value. If the transistor is used with its base open-circuit, the collector-to-emitter path acts like a zener diode wired in series with an ordinary diode.

The transistor's dynamic characteristics can be understood with the aid of Figure 6, which shows the typical forward transfer characteristics of a low-power npn silicon transistor with a nominal h_{fe} (current gain) value of 100. Thus, when the base current (I_b) is zero, the transistor passes only a slight leakage current. When the collector voltage is greater than a few hundred millivolts, the collector current is almost directly proportional to the base currents, and is little influenced by the collector voltage value. The device can thus be used as a constant-current generator by feeding a fixed bias current into the base, or can be used as a linear amplifier by superimposing the input signal on a nominal input current.

Figure 5. Static equivalent circuits of npn and pnp transistors.



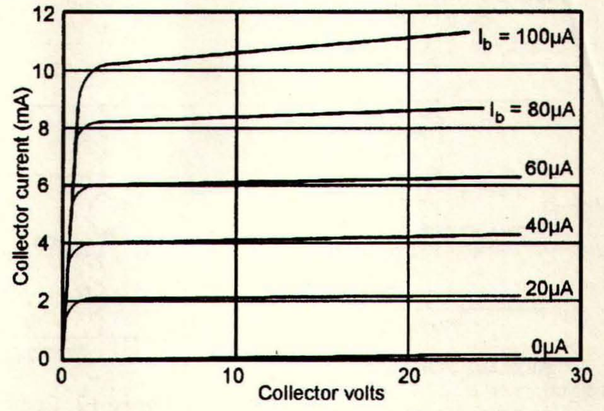


Figure 6. Typical transfer characteristics of low-power npn transistors with h_{fe} value of 100 nominal.

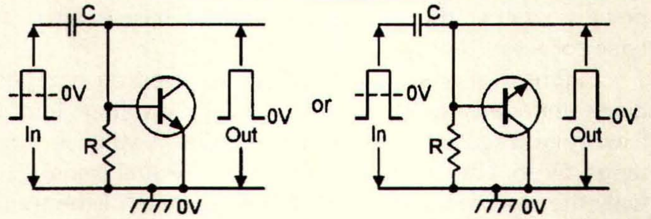


Figure 7. Clamping diode circuit, using an npn transistor as a diode.

PRACTICAL APPLICATIONS

A transistor can be used in a variety of different basic circuit configurations, and the remainder of this opening episode presents a brief summary of the most important of these. Note that although all circuits are shown using npn transistor types, they can be used with pnp types by simply changing circuit polarities, etc.

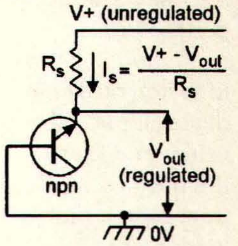


Figure 8. A transistor used as a zener diode.

DIODE AND SWITCHING CIRCUITS

The base-emitter or base-collector junction of a silicon transistor can be used as a simple diode or rectifier, or as a zener diode by using it in the appropriate polarity. Figure 7 shows two alternative ways of using an npn transistor as a simple diode clamp that converts an AC-coupled rectangular input waveform into a rectangular output that swings

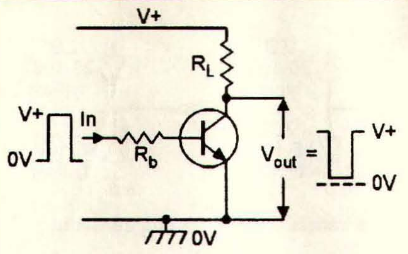


Figure 9. Transistor switch or digital inverter.

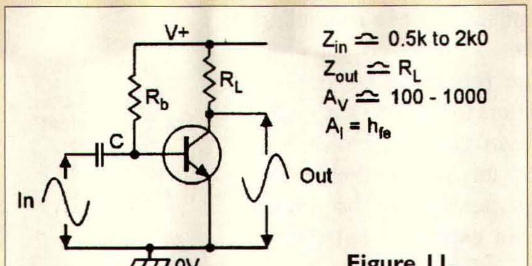


Figure 11. Common-emitter linear amplifier.

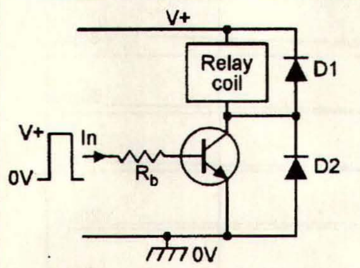


Figure 10. Transistor switch (digital inverter) driving a relay coil (or other inductive load).

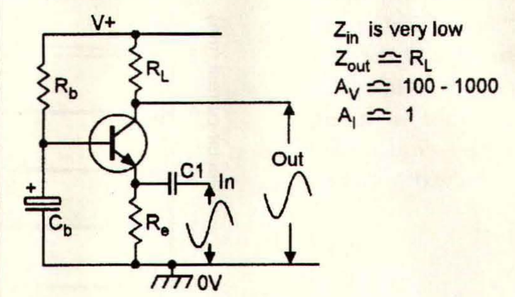


Figure 12. Common-base linear amplifier.

between zero and a positive voltage value, i.e., which "clamps" the output signal to the zero-volts reference point via either the transistor's internal base-emitter or base-collector "diode" junction.

Figure 8 shows an npn transistor used as a zener diode that converts an unregulated supply voltage into a fixed-value regulated output with a typical value in the range 5V to 10V, depending on the individual transistor. Only the reverse-biased base-emitter junction of the transistor is suitable for use in this application. If the reverse-biased base-collector junction is used, the zener value typically rises into the 30V-100V range, and the transistor may self-destruct (due to over-heating) at fairly low zener current levels.

Figure 9 shows a transistor used as a simple electronic switch or digital inverter. Its base is driven (via R_b) by a digital input that is at either zero volts or at a positive value, and load R_L is connected between the collector and the positive supply rail. When the input voltage is zero, the transistor is cut off and zero current flows through the load, so the full supply voltage appears between the collector and emitter. When the input is high, the transistor switch is driven fully on (saturated) and maximum current flows in the load, and only a few hundred millivolts are developed between the collector and emitter. The output voltage is thus an inverted form of the input signal.

The basic Figure 9 circuit is intended for use as a simple digital switch or inverter, driving a purely resistive load. It can be used as an electronic switch that drives a relay coil or other highly inductive load (such as a DC motor) by connecting it as shown in Figure 10, in which diodes D1 and D2 protect the transistor from high-value switch-off-induced back EMFs from the inductive load at the moment of power switch-off.

LINEAR AMPLIFIER CIRCUITS

A transistor can be used as a linear current or voltage amplifier by feeding a suitable bias current into its base and then applying the input signal between an appropriate pair of terminals. The transistor can, in this case, be used in any one of three basic operating modes, each of which provides a unique set of characteristics. These three modes are known as "common-emitter" (Figure 11), "common-base" (Figure 12), and "common-collector" (Figures 13 and 14).

In the common-emitter circuit (which is shown in very basic form in Figure 11), resistive load R_L is wired between the transistor's collector and the positive supply line, and a bias current is fed into the base via resistor R_b, whose value is chosen to set the collector at a quiescent half-supply voltage value (to provide maximum undistorted output signal swings). The input signal is applied between the transistor's base and emitter via capacitor C, and the output signal (which is phase-inverted relative to the input) is taken between the collector and emitter. This circuit gives a medium-value input impedance and a fairly high overall voltage gain.

In the common-base circuit in Figure 12, the base is biased via R_b and is AC-decoupled (or AC-grounded) via capacitor C_b. The input signal is effectively applied between the emitter and base via C1, and the amplified but non-inverted output signal is effectively taken from between the collector and base. This circuit features good voltage gain, near-unity current gain, and a very low input impedance.

In the DC common-collector circuit in Figure 13, the collector is shorted to the low-impedance positive supply rail and is thus effectively at "virtual ground" impedance level. The input signal is applied between base and ground (virtual collector), and the non-inverted output is taken from between emitter and

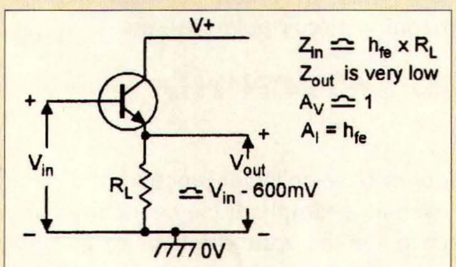


Figure 13. DC common-collector linear amplifier or voltage follower.

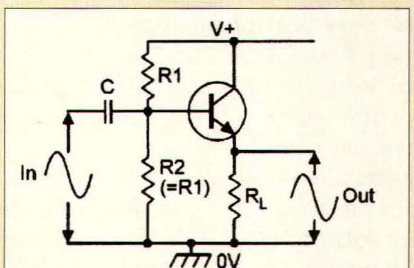


Figure 14. AC common-collector amplifier or voltage follower.

ground (virtual collector). This circuit gives near-unity overall voltage gain, and its output "follows" the input signal. It is thus known as a DC-voltage follower (or emitter follower) and it has a very high-input impedance (equal to the product of the R_L and h_{fe} values).

Note that the above circuit can be modified for AC use by simply biasing the transistor to half-supply volts and AC-coupling the input signal to the base, as shown in the basic circuit in Figure 14, in which potential divider R1-R2 provides the half-supply-voltage biasing.

The chart in Figure 15 summarizes the performances of the three basic amplifier configurations. Thus, the common-collector amplifier gives near-unity overall voltage gain and a high input impedance, while the common-emitter and common-base amplifiers both give high values of voltage gain, but have medium to low values of input impedance.

Parameter	Common collector	Common emitter	Common base
Z_{in}	High ($\simeq h_{fe} \times R_L$)	Medium ($\simeq$ 1k0)	Low ($\simeq$ 40R)
Z_{out}	Very low	$\simeq R_L$	$\simeq R_L$
A_V	$\simeq 1$	High	High
A_I	$\simeq h_{fe}$	$\simeq h_{fe}$	$\simeq 1$
Cut-off frequency	Medium	Low	High
Voltage phase shift	Zero	180°	Zero

Figure 15. Comparative performances of the three basic circuit configurations.

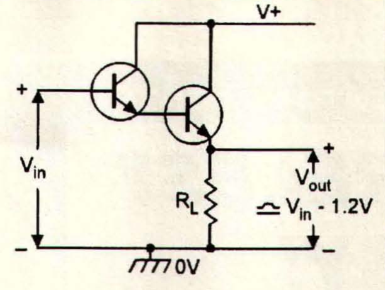


Figure 17. Darlington or Super-Alpha DC emitter follower.

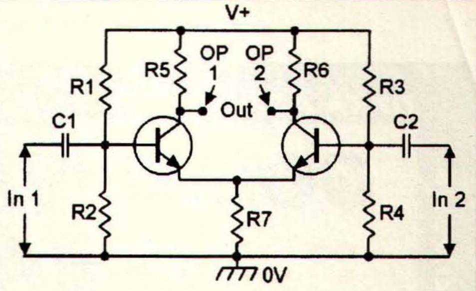


Figure 16. Differential amplifier or long-tailed pair.

THE DIFFERENTIAL AMPLIFIER

Figure 16 shows — in basic form — how a pair of amplifiers of the basic Figure 11 type can be coupled together to make a "differential" amplifier or "long-tailed pair" that produces an output signal that is proportional to the difference between the two input signals. In this case, Q1 and Q2 share a common emitter resistor (the "tail"), and the circuit is biased (via R1-R2 and R3-R4) so that the two transistors pass identical collector currents (thus giving zero difference between the two collector voltages) under quiescent zero-input conditions.

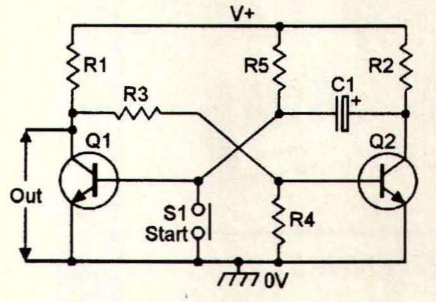


Figure 19. Manually-triggered monostable multivibrator.

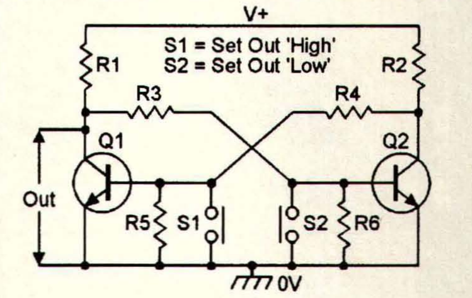


Figure 18. Manually-triggered bistable multivibrator.

If, in the above circuit, a rising input voltage is applied to the input of one transistor only, it makes the output voltage of that transistor fall and (as a result of emitter-coupling action) makes the output voltage of the other transistor rise by a similar amount, thus giving a large differential output voltage between the two collectors. If identical signals are applied to the inputs of both transistors, on the other hand, both collectors will move by identical amounts, and the circuit will thus produce a zero differential output signal. The circuit therefore produces an output signal that is proportional to the difference between the two input signals.

THE DARLINGTON CONNECTION

The input impedance of the Figure 13 emitter follower circuit equals the product of R_L and the transistor's h_{fe} values — if an ultra-high input impedance is wanted, it can be obtained by replacing the single transistor with a pair of transistors connected in the "Darlington" or Super-Alpha configuration, as shown in Figure 17. Here, the emitter current of the input transistor feeds directly into the base of the output transistor, and the pair act like a single transistor with an overall h_{fe} value equal to the product of the two individual h_{fe} values, i.e., if each transistor has an h_{fe} value of 100, the pair act like a single transistor with an h_{fe} of 10,000, and the overall circuit presents an input impedance of 10,000 x R_L.

MULTIVIBRATOR CIRCUITS

A multivibrator is, in essence, a two-state digital circuit that can be switched from the output-high to the output-low state, or vice versa, via a trigger signal that may be derived from an external source or via an automatic or triggered timing mechanism. Transistors can be used in four basic types of multivibrator circuits, as shown in Figures 18 to 21.

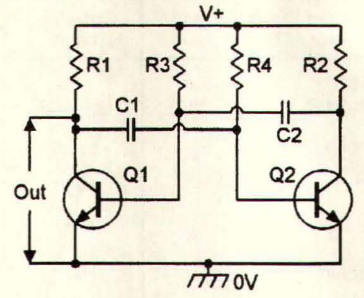


Figure 20. Astable multivibrator or free-running squarewave generator.

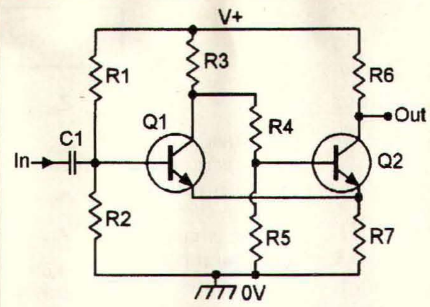


Figure 21. Schmitt trigger or sine-to-square waveform converter.

The Figure 18 circuit is a simple, manually-triggered, cross-coupled bistable multivibrator, in which the base bias of each transistor is derived from the collector of the other, so that one transistor automatically turns off when the other turns on, and vice versa.

Thus, the output can be driven low by briefly turning Q2 off via S2, thus shorting Q2's base-emitter path. As Q2 turns off R2-R4 feed base drive to Q1 base, the circuit automatically locks into this state until Q1 is similarly turned off via S1, at which point the output locks into the high state again, and so on ad infinitum.

Figure 19 shows — in basic form — a monostable multivibrator or one-shot pulse generator circuit. Its output (from Q1 collector) is normally low, since Q1 is normally biased on via R5, but switches high for a preset period (determined by the C1-R5 component values) if Q1 is briefly turned off by momentarily closing push-button "Start" switch S1.

The actual monostable timing period starts as the push-button "Start" switch is released, and has a period (P) of approximately 0.7 x C1 x R5, where P is in µS, C is in µF, and R is in kilohms.

Figure 20 shows an astable multivibrator, or free-running squarewave generator, in which the on and off periods of the squarewave are determined by the C1-R4 and C2-R3 component values. Basically, this circuit acts like a pair of cross-coupled monostable circuits, which automatically trigger each other sequentially. If the C1-R4 and C2-R3 timing periods are identical, the circuit generates a free-running squarewave output waveform. If the two timing periods are not identical, the circuit generates an asymmetrical output waveform.

Finally, Figure 21 shows a basic Schmitt trigger or sine-to-square waveform converter circuit. The circuit action here is such that Q2 switches abruptly from the "on" state to the "off" state, or vice versa, as Q1 base goes above or below pre-determined "trigger" voltage levels.

If the circuit's input is fed with a reasonable-amplitude sinewave input, the circuit thus generates a sympathetic squarewave output waveform. **NV**

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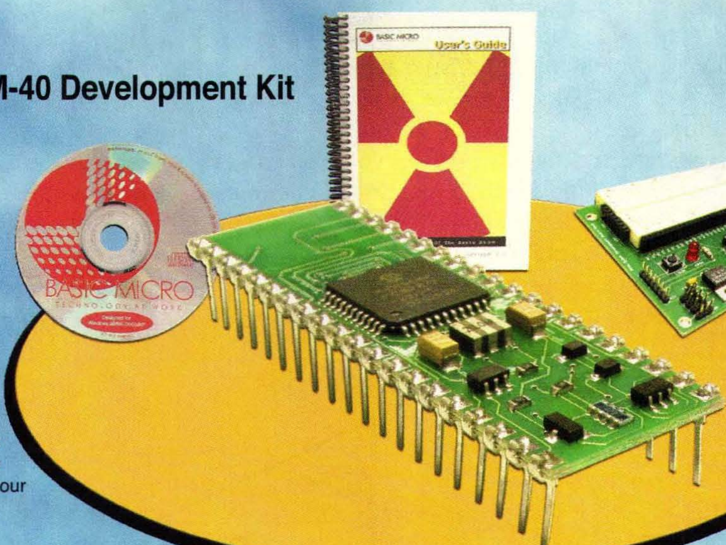

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Learning Forth: The Elegant Language for Microcontrollers and Robotics

by Thomas Henry

Forth is a slick language — fast, compact, and easy to learn — and is ideal for rapid development of solutions to complex problems.

With the advent of the digital revolution, it's become important for electronics enthusiasts to know more and more about software design, as well as the nuts and bolts of hardware. Most experimenters have a smattering of programming under their belts – maybe through early contact with simple languages such as assembler or BASIC, or perhaps by taking a recent college course in an object-oriented language like C++ or Java. However, depending on your age, there's one language you might not have seen or even heard of, and that's a pity. The language called Forth – dating from the 1970s and yet still evergreen – is one of the best choices for embedded applications involving data logging, control circuitry, or robotics. It's a slick language – fast, compact and easy to learn – and is ideal for rapid development of solutions to complex problems.

In some ways, Forth has been a well-kept secret among designers in the know. But programs written in it abound – you'll find them controlling Hollywood special effects cameras, bar code scanners used by parcel delivery services, NASA's space shuttles, mathematical research programs, giant mountainside telescopes, and homemade robots. Forth has even been used to implement other languages.

The purpose of this article is to show you how to get started programming in the Forth language. Its elements are overviewed, and you'll find out how you can get a copy of Forth free-of-charge to run on your own computer – be it a PC, Mac, or even a single board microprocessor system. Of course, one article can't cover a language in depth, so the real goal here is to whip up your interest and point you toward the required resources to teach yourself this fascinating programming language. There's no need for any classes – you'll find everything right here to begin your own stimulating regimen of self-study!

Let's dive into the deep end and see what Forth looks like and what makes it unique among all other computer languages.

What Makes Forth Different

Forth really is different! It combines elements of compiled, interpreted, and tokenized languages (like C++, Basic, and Java, respectively), and even shares properties with an entire operating system. Let's get specific.

If you boot-up Forth on a microcomputer, it takes over many of the usual tasks normally handled by the operating system. This includes such things as input from a keyboard, output to a video screen, and mass storage transfer to and from a disk drive. It provides a convenient environment in which to design and test programs – once you're in the system, you can stay there without having to shell out to other applications such as editors, compilers, assemblers, and the like. And Forth can be employed interactively, just like an interpreted language. You can use it as a simple calculator in realtime, or to immediately test new ideas at the keyboard without any wasteful intervening steps.

It can also be used like a compiler, allowing you to build up a collection of useful precompiled modules which can then be strung together to create more powerful applications. But the Forth compiler is very different from any you've ever seen. Most (take Microsoft's Visual C++, for example) are huge complicated affairs, designed to handle every conceivable legal combination of words and structures. Forth, on the other hand, divides the

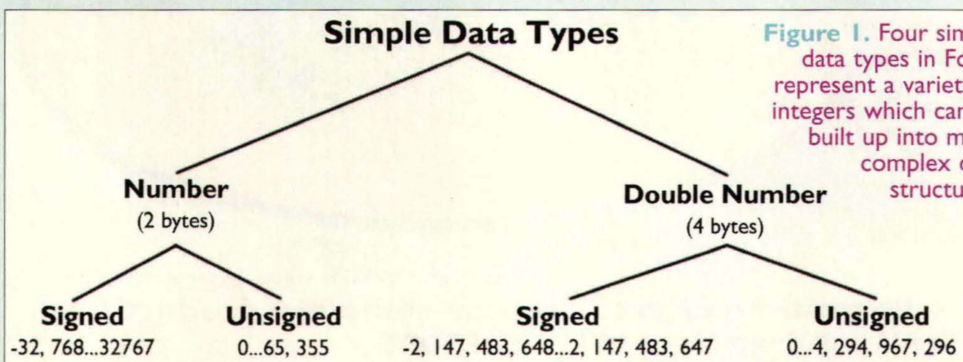


Figure 1. Four simple data types in Forth represent a variety of integers which can be built up into more complex data structures.

labor up into small and easily understood components. For example, there's a separate "compiler" (a compiling word, actually) which takes care of IF...THENs, another word to handle the multiplication of two numbers, and yet another to deal with DO loops. The beauty of this approach is threefold:

- Learning a handful of simpler compiling words as you go along is far easier than trying to master a huge, bloated standalone compiler all at once. Forth is great for beginners.
- The entire compiling system is extremely compact. Some amateur robotics experimenters have been able to boot up and customize Forth on a microcontroller single-board system in less than 2K bytes!
- Most importantly, by taking the "each word is its own compiler" approach, you now have the ability to extend the language any way you want. If you need some sort of new loop, data structure, or exotic numerical function, say, then you can easily create it and add it to the language. The Forth system on your computer can grow any way you see fit — you're not stuck with having to upgrade to the next version of a compiler.

Continuing with our overview of Forth, the next notable feature is that the language is stack based, employing the efficient Reverse Polish Notation. This will be immediately recognizable to anyone who's ever used a Hewlett-Packard pocket calculator. A stack is a portion of memory that behaves in a last-in first-out (LIFO) manner. As a simple example, a stack of magazines is a LIFO structure. Whatever issue you put on top last will be the one you must remove first, before you can access any of the others below it.

For instance, if you wish to add 3 to 4 in Forth, you "push" the numbers 3 and 4 onto the stack first where they can sit until needed. To add them, simply execute the word + (plus) which "pops" the two numbers from the stack, adds them, and returns the sum back to the stack. The beauty of Reverse Polish Notation is that it completely eliminates the need for muggling around with parentheses and yet easily handles the most complex of numerical expressions.

Another advantage of a stack-oriented language like Forth is that it greatly reduces the reliance on temporary variables or named memory locations. Most of the computational activity centers on the stack, with subtotals being stored there as long as desired.

Actually, to be precise, the Forth system usually employs more than one stack. There's a data stack, such as the one mentioned above, and a separate stack that holds the equivalent of subroutine return addresses, among other things. Both of these are completely accessible to the programmer and easy to get the hang of.

Data Types in Forth

Every language contains several simple data types from which more complex data structures can be built. In Forth, the simplest data type is called a single-length number, or just number for short. A number in Forth is nothing more than an integer maintained in two bytes. There are Forth words that can treat this as a signed integer, and some that let you consider it to be unsigned, yielding twice the range. See Figure 1.

As mentioned earlier, Forth is an extensible language, so it's easy to enhance its capabilities and permit the use of double numbers. These are stored as four bytes. This greatly increases the spread of values that can be represented, up to around ± two billion if signed, and zero to four

Where You Can Get Forth for Free

Thanks to the Internet, it's never been easier to find a copy of the Forth language for your machine — and free of charge. You can download versions for older DOS machines, Windows, Macs, various microcontrollers, and even the Palm Pilot. Several specific recommended versions are listed below, but if you don't see one that matches your needs, be sure to poke around on the web sites mentioned.

FF by Tom Zimmer and other contributors is my favorite. It is slick, full of wonderful help and debugging features, and runs very quickly even on older 286 DOS machines. It includes a great text editor, assembler, and metacompiler, and even some exotic add-ons like floating point capabilities. You can download the free package from the *Nuts & Volts* web site at **www.nutsvolts.com.**

Pygmy Forth, by Frank C. Sergeant, is another freebie that runs extremely well on slower, older DOS computers. I like this one because it is minimalist — you can master all of its words in very short order. Best of all, it incorporates an easy-to-use metacompiler which lets you create new versions of the language to include whatever features you deem to be important. Download it at **www.simtel.com/pub/msdos/forth**.

MVP-Forth is a very complete package for DOS computers, too. I believe this was a commercial implementation at one time, but its publisher, Mountain View Press, has released it as freeware now. Included in the download is a great manual/tutorial that you can print out and work through as self-study. You can FTP this one directly from **ftp.forth.org/pub/Forth/Archive/ibm/make-mvp.exe**.

If you're looking for a more extensive compiler, then try out the popular Forth-PC for DOS, by the ubiquitous Tom Zimmer (author of many interesting Forth implementations). You may want to start simpler and graduate to it, since it includes hundreds of new words and features. You'll also find this one at the popular Simtel site **www.simtel.com/pub/msdos/forth**.

But if programming for a Windows environment is important to you, then take a look at Win32Forth 4.2. Also by Tom Zimmer and colleagues, this is starting to become a complex affair, and is perhaps best explored after mastering one of the simpler compilers mentioned here first. With it, you get Forth control over windows, menus, mousing, graphics, and all the features you'd expect in a GUI-type interface. Download it for free at **www.taygeta.com/forthcomp.html**.

Finally, if you don't see what you're looking for here, then check out the software library at the UK Forth Interest Group's web site. They have all sorts of cross-compilers and the like for microcontrollers, Macs, and other machines. Just aim your browser at **www.figuk.plus.com/4thres/systems.htm**.

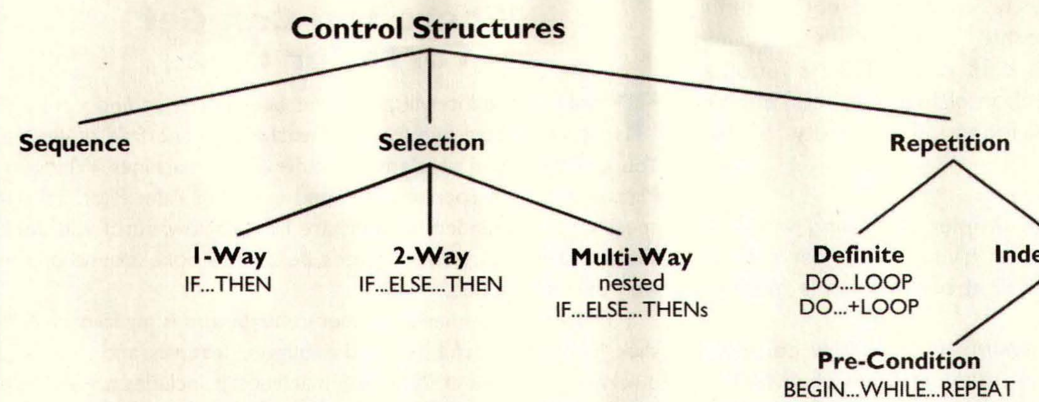


Figure 2. Forth provides several convenient variations on the three essential control structures.

billion if unsigned. Most Forth packages come with the double number data type already installed.

At this point, you're probably jumping out of your chair and exclaiming "what about fractions?" As a matter of fact, Forth, in its purest form, is an integer-based language, but that doesn't mean that you can't deal with fractional quantities. To see why, first consider how other languages deal with this problem.

The so-called floating-point format is typically used to handle fractions. For example, as humans we might visualize the number 507-2/3 as 507.666 ... where the sixes go on forever. A pocket calculator might display this as 5.076666E2 which means we are to multiply 5.076666 by 102. 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.

The trouble is, when computing with a bunch of numbers, the decimal points typically have to be aligned similarly before the arithmetic can happen — the points may "float" left or right depending on the sizes of the numbers and the required precision. For this reason, floating-point operations are inherently less efficient than simple integer arithmetic (which microprocessors can handle directly). Perhaps more importantly, floating-point numbers are often just approximations to actual values. In the example above, 507.6666 is not exactly 507 2/3. If your program is adding, subtracting, multiplying, and dividing thousands of floating point approximations, it is possible that the imperfections will accumulate to the point where the final result is substantially in error.

Forth gets around all of this nastiness with two admirable features. First, there are a variety of arithmetic operators which keep track of results including a remainder. For example, just like a grade school child might do, Forth will divide 513 by 7 yielding both a quotient (73) and a remainder (2). Note that this answer of 73 with a remainder of 2 is exact, and not an approximation — no rounding, no truncation, but exactly right.

As for fractions, you can handle these in Forth as well, using what's known as fixed-point representation. Here's an easy way to think of it. Suppose you were writing a program to balance a checkbook. Simply scale everything up by 100 and perform all calculations in cents. For example, $12.34 would simply be stored as 1234, $0.75 would be 75 and so on. When it's time for your program to spit out a finally tally, merely have the output routine stick a decimal point in two places from the right. Simple, fast, and elegant!

By the way, Forth already contains several arithmetic operators for scaling fixed-point numbers up and down, and even for inserting a decimal point into the final result. While this approach may seem foreign at first, with practice, it soon becomes second nature. And of course, you'll get exact results in a much quicker runtime.

But if you really feel that you just can't live without floating-point numbers, then you'll be interested to learn that some of the Forth packages kicking around include this capability as an add-on.

Okay, so much for simple numbers, but what about data structures? This is where Forth really shines. It is frequently the case in programming (especially in data logging applications) that you will need more complex data structures like arrays, matrices, strings, records, and so on. Forth has a whole slew of built-in words that let you design just about any type of new data structure you can conceive of. Best of all, you have total control over how the component items will be stored internally, meaning that Forth's data structures are typically very space-efficient.

Control Structures

A control structure is a way to alter the normal flow of a program. Corrado Böhm and Giuseppe Jacopini proved back in 1966 that any solvable problem in computer science can be handled by nothing more than three simple control structures. These are called sequence, selection, and repetition. Forth has words to implement all three of these and in various useful forms. See Figure 2.

The simplest is little more than a list of statements that are executed in sequence, one after another. Naturally, this is easy to handle in Forth. As you put together a new word made up of older ones, Forth merely creates a list of addresses corresponding to the existing words you wish to invoke. This is an extremely efficient way of handling things, since the list of addresses takes up very little room. For example, if you were designing a computer-controlled lighting system for a small theater, you could define a new word called GOODNIGHT to be used when the actors are taking their curtain calls:

```
: GOODNIGHT    0 HOUSELIGHTS 0 FOOTLIGHTS 1
SPOTLIGHT ;
```

In Forth, the colon signifies the start of a new compiled definition — in this case, labeled GOODNIGHT — the semicolon indicates the end. The words in between will be executed sequentially. Recalling that Reverse Polish Notation is used, a zero representing an "off" condition is pushed onto the stack. This is then acted upon by the word HOUSELIGHTS, which will trigger the relays controlling the house lights and turn them off. In a similar way, the footlights will be extinguished. Finally, a 1 (meaning "on") is processed by the word SPOTLIGHT, which fires the relay controlling the spotlight, illuminating the actor taking his or her bow.

The second control structure, selection, comes in three flavors. A one-way selection either decides to perform some action or it doesn't, based upon the truth-value of a flag currently on the stack. For example, you might want to have an invoice program add on $5.00 shipping and handling if an order falls below $25.00. Assuming the merchandise total is currently on the data stack, here's a definition to adjust a customer's billing statement:

```
: ADJUST   DUP 25 < IF 5 + THEN ;
```

While the order of the words might surprise you, it's pretty easy to unravel this sentence. Let's suppose a merchandise total of $17.00 is currently on the data stack. When ADJUST is executed, the word DUP will duplicate the value 17 since we'll need a copy of the number to test in just a moment. Then the cut-off number 25 is pushed on top of the two 17s. The less-than operator compares the top two numbers, and since 17 is indeed less than 25, a result of "true" (actually, any non-zero number) is pushed onto the stack atop the original 17 which is still there.

Next, the IF word sees the flag, destroying it in the process, and since its value is true, the number 5 is pushed onto the stack where it is then added to the 17 patiently waiting there. A final value of 22 is left. Had the comparison worked out to be false, control would have skipped over the words between IF and THEN, indicating an order of $25.00 or more had been placed and no surcharge was to be added.

Continuing, a two-way selection provides two paths that can be taken, depending on whether a flag is true or false. In Forth, this is implemented with the words IF...ELSE...THEN. Again, don't let the order fool you — you'll soon get used to thinking this way.

Finally, a multi-way selection structure that lets you choose from any number of options can be handled by nesting a bunch of two-ways. In some versions of Forth, the designers have thoughtfully provided a CASE structure as a more elegant means to implement this.

The last major control structure is called repetition. There are two basic forms of this: definite and indefinite. In a definite repetition, the number of desired iterations is known at the outset. A DO...LOOP is used for this in Forth, and the words inside will be executed repeatedly a given number of times with an index which counts by ones. A variant of this, DO...+LOOP, can be used to count by some multiple other than one, even backwards, if desired (just use a negative step value).

As the name implies, an indefinite repetition is one which loops indefinitely, monitoring some condition to determine when to halt. There are two versions of this — again, see Figure 2. A pre-condition loop checks a flag before doing anything else and will execute as long as that flag is true. In this way, it is possible to skip execution of the structure entirely if the condition should happen to be false at the outset. Here's an example of a pre-condition loop which can be used to implement a computer-controlled sprinkler system in a greenhouse:

```
: MONITOR   BEGIN ?DRY WHILE SQUIRT REPEAT ;
```

Where You Can Learn More

Teaching yourself Forth needn't be a costly affair. In fact, the Internet is packed with many excellent and free resources to help you master this elegant and powerful language. You'll find tutorials, documented source code, implementation manuals, and even complete books in PDF form which can be downloaded and printed at leisure. Here are just a few of the many web sites you might want to investigate.

Your first stop should probably be the Forth Interest Group (FIG). This non-profit assembly has been going since the 1970s, and continues to be one of the best central clearing houses for anything to do with Forth. In fact, many of its members have contributed in a very direct way to the development of the language. You'll find all sorts of documents and downloads here, so fire up your browser and check out their extensive web site at **www.forth.org**.

Another superior site is maintained by the UK Forth Interest Group. Among the interesting guides you'll find here is a how-to-do-it on designing your own Forth system from scratch. This British group also has a large number of Forth language packages you can download for free. Look them up at **www.figuk.plus.com/map.htm**.

Taygeta Scientific maintains a hefty web site chock full of free manuals, guides, tutorials, and compilers. This may be one of the most extensive download collections on Forth anywhere. Visit them at **www.taygeta.com/forth.html**.

Mountain View Press, one of the early promoters of Forth, also has a great accumulation of interesting files you can access for free. You can see what they have at **http://theforthsource.com**.

Another valuable collection of links can be found in The Open Directory. This group doesn't create new material, but rather organizes collections of sites having to do with a particular topic — in this case the Forth language. Think of the people at The Open Directory as librarians — they help you sort through the morass of information out on the Internet. See for yourself at **http://dmoz.org/Computers/Programming/Languages/Forth**.

Finally, don't forget about Usenet News Groups. There are several sections out there, including the very active **comp.lang.forth**. This is a great place to share ideas and mingle with other Forth aficionados.

?DRY is a pre-defined word that takes a reading from an electronic hygrometer connected to one of the microprocessor ports. If the relative humidity drops below 75 percent, for example, then this probe outputs a 1. Otherwise, its value remains at 0. Each time Forth makes a pass through the loop, it checks the hygrometer. If the value is 1 (true), then it executes the SQUIRT function which turns on a relay-controlled sprinkler for a quick dose of water. When the word REPEAT is hit, program flow loops back to the word BEGIN and the process starts over again.

BEGIN...UNTIL is a post-condition loop, and is the opposite of the above. The iterations will continue as long as a certain condition is false, halting only when the indicating flag turns true. It also differs in that the condition is checked at the end of the loop. For this reason, the BEGIN...UNTIL repetition is always guaranteed to execute at least once.

I/O and Disk Operations

Forth has a variety of words for easily handling input/output operations. For example, there are words to fetch input from the keyboard as individual keystrokes, entire strings of characters, and even to parse complete sentences into individual components. Likewise, a goodly selection of words will let you output characters, strings, formatted numbers, and so on either to a video monitor or printer. In many ways, Forth is an ideal language for handling keyboard/video operations since it offers such complete control over the formatting. And yet, massaging this data into an acceptable form is remarkably easy. There are all sorts of clever things you can do with Forth to express quantities as dates, times, phone numbers, dollars-and-cents, and so on.

While a disk drive is certainly not required to use Forth, its availability will simplify your development work substantially. Forth was invented back when RAM and other system resources were quite expensive, and as such, tries to make efficient use of them. For example, most of the earlier versions employ a disk block arrangement to implement a virtual memory scheme. That is, blocks are swapped to and from the disk as required, making it seem as though you have a great deal of RAM at your disposal.

The basic idea is elegant, but a disk block system is somewhat clunky by today's standards. So, more recent versions have replaced this aspect of the language with a simpler and more recognizable sequential file system. You write your code as a text file, save it to disk, and simply load it back whenever you want it.

Editors, Assemblers, Metacompilers, and Turnkeys

To really get cranking and churn out some productive code, you'll need a few extras. Fortunately, these are usually included with most free Forth packages. Let's take a look at them and see what they're all about.

While it is indeed possible to develop and test new words in Forth directly from the keyboard (remember, it's a highly interactive language), for best efficiency you'll no doubt want to create, edit, and save source code on disk. This calls for a good editor. If you're using a package featuring the virtual memory disk block system alluded to above, then the editor will probably be a somewhat awkward line-oriented affair, not unlike the EDLIN program of DOS days.

But more recent versions will include a fairly sophisticated and efficient WYSIWYG text editor. In either case, however, remember that Forth is a completely extensible system. If there's something about the editor that you don't like, change it! In a nutshell, the editor is nothing more than a Forth word built from simpler Forth words and can be modified as required.

In most languages, it can be a trifle messy if you need to embed assembler code in a program, but not so with Forth. Most versions come with a built-in assembler, and it's a snap to switch back and forth from high-level Forth to assembly language. There's an important ramification here. One can always design a new word in Forth.

For example, say you want to poll an input port to monitor a serial device, knowing full well that the operating speed won't cut it. No sweat! Write the code and convince yourself that it works at greatly reduced testing speeds. When you feel certain you've got all the kinks worked out, rewrite the word in assembly language to take advantage of the microprocessor's full capability.

You can use the high-level word as "pseudo-code," patterning the assembly language version after it functionally. Then simply delete the old version, replacing it with the new, peppy rendition and away you go. Since Forth readily lets you move between high-level and low-level words, development time can be far less than in other languages.

A metacompiler really opens things up for some fancy customization work. In short, this is a compiler which compiles a compiler! To make sense of this, you need to know that all Forth packages come with complete source code for the system itself. Using the built-in editor and assembler mentioned above, you can then tailor the system to fit your specific needs. You can add words, remove words, change screen displays, customize colors, and so on.

Next, invoke the metacompiler which cranks through the modified source code, compiling it into an executable program. You'll end up with a new version of Forth containing only those features you deem to be important. The user literally has the absolute power to create a whole new Forth operating system and vocabulary at will.

The turnkey capability is similar, but is used to craft custom applications rather than an entire operating system. For example, the greenhouse application mentioned above wouldn't really require an editor or assembler (and perhaps a whole slew of other words), so you can delete them and compile a specialized standalone version to distribute to nurseries.

Start Learning Forth on Your Computer

If this all sounds exciting to you, then now is the time to act! Start by locating a version of Forth that is suitable for your computer. The sidebar lists a number of sources from which you can download packages free-of-charge. In some cases, these implementations are quite fancy and every bit of commercial quality.

If you have a choice of machines, I really recommend you start with a simpler DOS version (like Pygmy Forth). I say this because these packages are compact, yet fast and thorough. They contain fewer predefined words making it easier to get a handle on the heart of the system. And working from DOS really feels so much more "immediate" — you can rapidly try out ideas and see what happens.

If you're feeling brave, however, you might want to try out some of the more extensive systems mentioned in the sidebar. These contain more features and more words (perhaps even in the thousands!) which can be a trifle confusing at the outset. In any event, you probably won't really want to get into Windows-type programming until you master the basics of the simpler DOS versions.

Incidentally, now's a good time to mention that there are a number of Forth dialects, typically differing only by a handful of words. This shouldn't slow you down too much, but do be aware that as you move from one package to another, you may have to adjust your vocabulary somewhat.

Okay, if you've got a Forth system booted on your computer, jump right in and start tinkering. I think you'll find this to be a pleasant and rewarding activity. You won't need to sign up for any classes — all it takes is curiosity and a willingness to keep trying things out at the keyboard.

If you can find a good Forth book at your local library, all the better. But the truth of the matter is that every Forth system contains the most important learning tool within it. Recall that a typical package comes with the complete source code (so the metacompiler can do its thing). This is a wonderful educational aid. Start by loading Forth's source into the editor and work through it page by page. Check to see how words have been defined in terms of other words, and note how they manipulate the stack. Use deduction, intuition, and even wild guesses to formulate experiments you can try at the keyboard to get a better understanding. The nice thing is, Forth source code (depending on the skill of the writer) can be very self-documenting. With practice, you should find yourself reading through the words as though it were your native language.

Another great help when you're first starting is to download a tutorial or installation manual off of the Internet. Check the sidebar on where to learn more. There's a ton of good, free material out there that is perfect for helping a beginner get started in this remarkable language.

Of course, this article has just scratched the surface of what makes up Forth and there's still a lot more for you to learn. But in the final analysis, it's not a magazine article, or book, or even a teacher that matters most when learning a computer language (and I say this as a former college professor). Rather, it's the student who teaches himself or herself, guided primarily by persistence and curiosity, trying things out to see what happens, and learning through experience. You've got the tools now (free ones at that!), so dig in and start learning Forth today. **NV**

Thomas Henry is the author of over 120 articles and six books on the subjects of electronic design, microcomputers, music synthesizers, astronomy, caves, and magic. While in school, he performed in a zany music-comedy group, playing guitar and singing bass. After obtaining an M.A. in mathematics, he taught at the collegiate level for 14 years.

Forth for Controllers and Robotics

It's been said that 98 percent of all the microprocessors manufactured end up in embedded equipment like controllers and robotics; personal computers account for the slender remainder. Since Forth is so compact and runs so fast, it's only natural that this adaptable language has been pressed into service throughout the electronics industry. There are a number of excellent web sites out there which delve into the topic of using Forth in single-chip, controller, or robotic applications. Here are a few to whet your appetite.

The web site of Ultra Technology sports a comprehensive listing of most of the Forth chips ever produced. This is a great place to get started. It'll give you a feel for just how common Forth controllers have been and continue to be. Look for it at **www.ultratechnology.com/chips.htm**.

Nuts & Volts author, Karl Lunt, maintains a homepage filled with all sorts of robotics information, including some projects where Forth successfully ran a system in just a couple kilobytes of RAM! His site is **www.seanet.com/~karllunt/**.

New Micros Incorporated stocks a wide range of microprocessors and single board computers featuring Forth as the operating system and programming language. These range from Motorola chips like the 68HC11 to Intel types like the 8051. Their web site is at **www.newmicros.com**.

Anyone who's interested in Forth as a controller language ought to read over Jeff Fox's article *Forth — the LEGO of Programming Languages*, which he has posted on the Internet. It gives great insight into just why this language is such an efficient one to design with. Read it at **www.ultratechnology.com/4thlego.htm**.

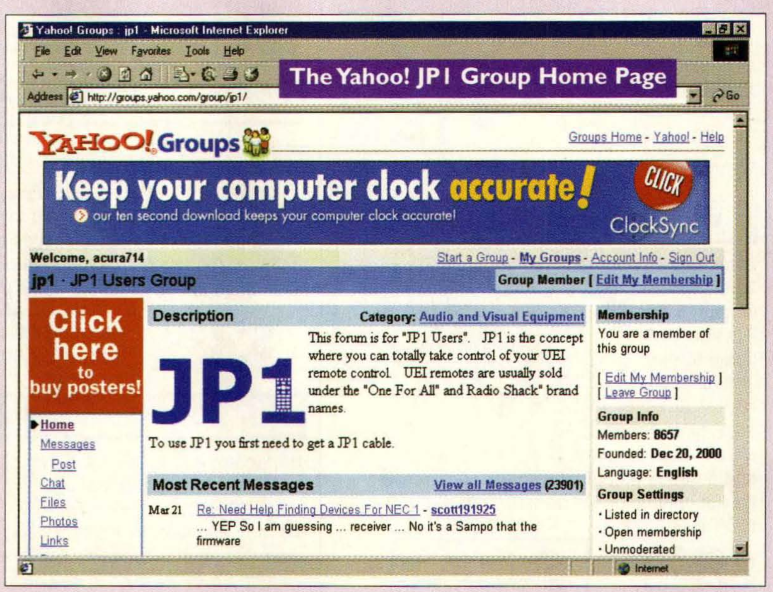
Cracking the Easter Egg in Your Universal Remote

Discover a "secret" computer interface for your remote control.

by Michael Weingarden

Like many people, I received a new universal remote control as a gift during the holidays. It wasn't my first, but I was hopeful that it would do more than its predecessors.

I enjoy tweaking gadgets almost as much as using them. I also like discovering Easter eggs on DVDs. For these reasons, I was doubly delighted when I discovered a "secret" computer interface for my new remote control.



The Yahoo! JP1 Group Home Page

The Problem

The biggest problem with my old universal remote (a Sony RM-VL900) was that when the batteries died (or were borrowed), I had to reprogram the thing. This was no small task, and I've had to do it more than once. I won't go through all of the nasty details, but I can tell you it involved stuff like finding the owner's manual, researching "preset" codes, mashing buttons in the proper order, and "learning" signals from other remotes.

I became acquainted with this process when my teenage stepson decided to borrow the batteries from my remote for his portable CD player. Eventually, I took the time to write down every step that was required to reprogram the remote, but I was hopeful that one day an easier way would present itself.

I eyed the new remote (an RCA RCU810b) with cautious optimism. I pored through the manual looking for some hint that this remote would solve all my problems and introduce me to new "solutions" that I hadn't even thought of yet. Unfortunately, the manual revealed little that was exciting or new. According to the manual, the remote was actually less powerful than my current remote.

Undaunted, I began to search the Internet to see if I could dig up any dirt on the RCU810b. At Google, there was a payoff for my hopeless optimism. The RCU810b was being discussed in a forum at **RemoteCentral.com**. After reading several posts, I stumbled across a discussion thread regarding the JP1 interface. This, my dear reader, is why you are reading this article.

The Solution

The RCU810b and several other remotes — sold under the brand names One For All and RadioShack — have an undocumented, secret interface that allows you to program the remote from your computer (PCs only right now, sorry Mac fans). There are several ways to determine whether a remote offers the JP1 interface:

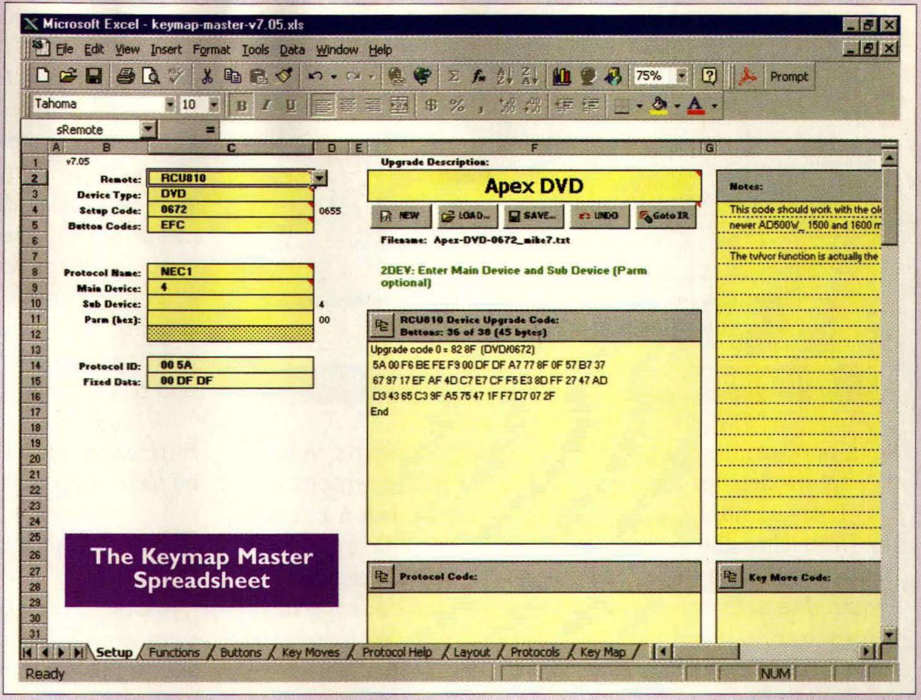
1) Open the battery door and look for a six-pin connector or six solder holes in the exposed circuit board. The JP1 interface should be easily visible when you open the battery door.

2) Go to one of the following web addresses for lists of JP1 compatible remotes:

http://jp1.filebug.com/remchart.htm
www.hifi-remote.com/jp1/remotes.shtml
http://home.austin.rr.com/xris/jp1/jp1FAQ.htm

What's so great about a computer interface, you may ask? The computer interface makes it a lot easier to program the remote and infinitely easier to back-up all of your hard work. In addition, you can store a lot more information in the remote using the computer than you can by "learning" from other remotes.

There are already a bunch of universal remotes on the market that have documented, company-supported computer interfaces — so why bother "hacking" a remote? One reason to hack your remote is to save money. According to **Remote Central.com**, computer interface remotes sell for anywhere from $200.00 to $1,000.00. Compare that to JP1 remotes that can be found for $30.00 at various sites including eBay, Yahoo! Shopping (search for rcu810 or urc 8910), or RadioShack (model 15-2116).



The Keymap Master Spreadsheet

To be perfectly fair, there is a slight extra cost for using a JP1 remote. A cable is required to attach the remote to the PC's parallel port. You can build this cable yourself or buy a premade cable from **www.jp1.filebug.com** for $20.00 (including shipping). If you decide to get an RCA RCU810 remote, you can send your remote to **filebug.com** to have them add the six-pin header for another $15.00. So, by the time you are done, a JP1 remote will cost you between $50.00 and $65.00 — still a bargain compared to $200.00 or more for a stock model.

The most important reason to hack your universal remote, though, is that it's fun. What joy can be had from using a universal remote that is designed to communicate with a computer? I'd much rather hack my way through the jungle of required hardware and software to get at the forbidden fruit of my universal remote.

Required Software and Hardware

- A PC with a parallel port (address 378h)
- JP1 interface cable ($20.00 from **www.jp1.filebug.com**)
- Ir.exe software (freeware)

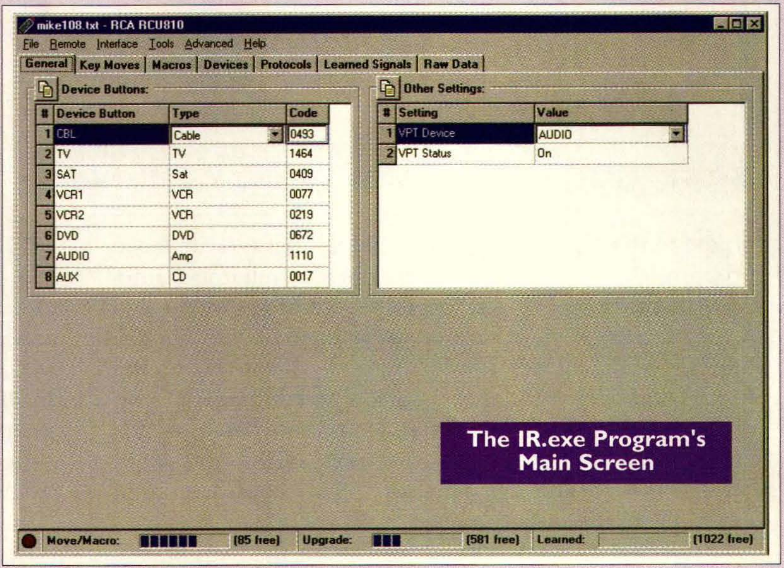
If the remote does not have preset codes for all your devices, these are also needed:

- Microsoft Excel 97 or above
- Keymap master spreadsheet (freeware)
- Upgrade codes for any devices that aren't preset in your remote (free)

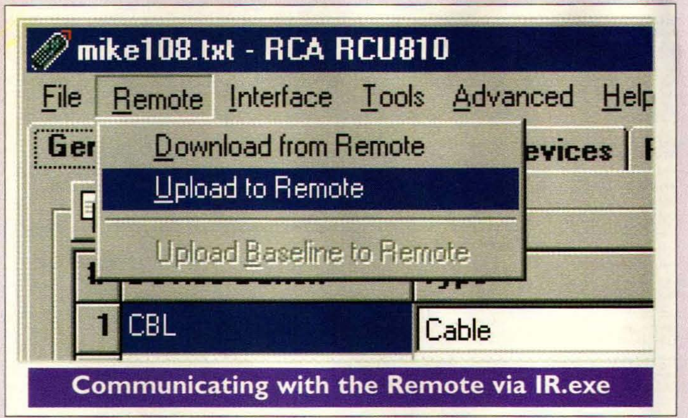
Remotes that offer the JP1 interface all have one thing in common. They are all made by a company called Universal Electronics. Unfortunately, neither Universal Electronics nor the original equipment manufacturers (like One For All and RadioShack) offer any information about the JP1 interface. All the programs and data are supplied for free by a community of technicians, engineers, and programmers working together for one common goal — nerdvana! This community resides in cyberspace at the Yahoo! JP1 group.

You can download all the software and data files that are required from the JP1 group (**http://groups.yahoo.com/group/jp1**). You must "join" the JP1 group to access the files, but joining is quick and painless and absolutely essential for JP1 hacking. All of the required files are located under the Files folder at the JP1 group.

The main file that is required is the Ir.exe program — Ir stands for infrared. The program can be found in the Tools folder under the Files folder. The program allows you to upload data to the remote or download data from the remote. You can download the data from the remote to save the work that you have already done manually. You can also use the Ir program to change the functions that



The IR.exe Program's Main Screen



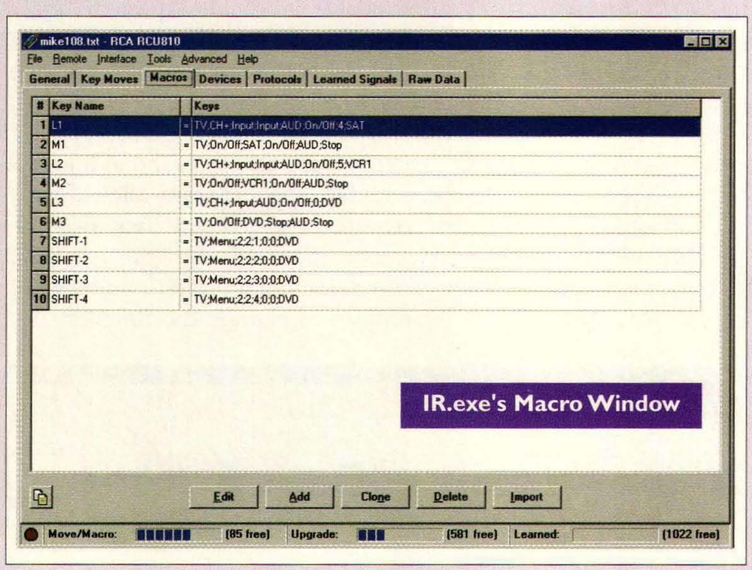
Communicating with the Remote via IR.exe

keys perform, to create macros, and to allow the remote to operate devices that weren't "preset" in the remote.

The Keymap Master (KM) — no, this is not a character from Ghostbusters — is the second most important piece of software for JP1 hacking. The KM spreadsheet is required to add support for devices that don't already have a preset code in your remote. With the KM, you can also remap any device function to any key. When you have everything the way that you want, the KM generates special codes that you can copy and paste into Ir.exe.

My Adventure

I started by programming the remote the old fashioned way — I followed the manual and used all the presets that I could. Next, I used the JP1 cable to connect the



IR.exe's Macro Window

remote to the PC's parallel port. When I first ran the Ir.exe program, there was a problem with the interface autocheck feature, so I had to go to the Interface menu and uncheck auto-check. After that, all I had to do was choose Remote -> Download. I was amazed to see all of the devices and device codes that I just entered manually staring back at me from the computer screen. Then, a chill went up my spine as I realized that all of my hard work was now saved and available for modification later with only a few clicks of the mouse.

I still had to configure the remote for the two devices that did not have preset codes. I had one device that had no preset code (my Apex AD-1500 DVD player) and a device that didn't have the buttons mapped properly (my Harman Kardon AVR-110 audio/video receiver). Fortunately, others in the Yahoo! JP1 group had already taken the time to figure out how to upgrade the remote to work with these devices. So, I downloaded the device code files from the Files -> Device Codes folder. There wasn't a specific device code file for my Harman Kardon AVR-110, so I downloaded the one for the Harman Kardon AVR-300 instead. After finding the appropriate files, all I had to do was load them into the KM spreadsheet and then copy and paste the upgrade codes into the Ir.exe program.

I did run into a problem when trying to get the Harman Kardon AVR-110 to work, but I found the solution by searching through the messages at the JP1 group.

The Macros

One of the most powerful uses for the JP1 interface is programming macros. Macros allow your remote to accomplish a number of tasks with only one keystroke. With the JP1 interface, I can assign macros to any key.

There are two commons uses for macros:

1) Turning on and configuring all devices required to play a DVD, a VHS tape, or a show on satellite TV.

2) Navigating commonly-used, but cumbersome menus.

When I got my first universal remote for my TV, VCR, and cable box, I was happy to eliminate the clutter on my coffee table. However, it still took a bit of effort to get everything up and running and configured appropriately. Things got even worse when I finally got a DVD player and audio/video receiver. Moreover, for my family, operating the whole system was really terrifying. With my old remote, I could program macros to automate some of the work, but programming macros was a hassle and I could only assign the macros to a few keys. Therefore, I was anxious to see what the JP1 interface could do for me. My RCU810 remote has extra buttons available specifically for macros. I decided to assign one button (L1) to setting everything up for satellite TV viewing. This included the following button sequence:

SAT, AUD, On/Off, 4, TV, Channel Up, Input, Input

The SAT button turns the satellite decoder box on. The combination of AUD and On/Off turns the audio/video receiver on. The number "4" tells the audio/video receiver to direct the satellite signal to the television. TV turns the television on. The next part (Channel Up, Input, Input) is a little trick I learned from the JP1 group. It sets the video input mode on the television. For some strange reason, you can't just tell the TV — go to SAT video mode.

I then programmed another button (M1) to store the macro for turning everything off related to satellite TV

Pluses and Minuses of Three JP1 Remotes

RadioShack 15-2116
You can get it at any RadioShack – it supports eight devices and it has an LCD screen. It doesn't have many extra buttons that you might use for macro programming.

RCA RCU810
It has a cool blue backlighting, six extra buttons, and it works great with RCA devices. You'll have to take the remote apart to solder in the six-pin connector required for JP1.

One For All URC-8910
Lots of extra buttons and a really cool look. It stores information that it learns on a separate EEPROM so you can't look at the learned information – this is only important if you really want to get dirt under your fingernails.

viewing. I actually could have made L1 turn things off and on, but my audio/video receiver requires a separate ON and OFF button. I then assigned L2 and M2 to do these things for VCR use and L3 and M3 for the DVD player.

When all was said and done, I had only one button to press to turn everything on and configure things appropriately, and one button to turn everything off. This was one of the few projects where I may have actually saved myself some time and effort by rewiring a perfectly good and working product.

With JP1, not only can you assign macros to most of the keys on the remote, you can assign macros to "shifted" keys, as well (on the RCU810, the shift key is the "Code Search" key). Once the macro is loaded into the remote, you just press and release the "shift" key and then press the key the macro was assigned to. This effectively doubles the number of keys that are available. Of course, my wife asks me, "Is that good or bad?"

Aside from turning things on and off, another great use for macros is to quickly navigate commonly-used, but cumbersome menus. I was getting sick of navigating the menus to control the brightness on the TV. I found that some DVDs were really dark and some were really bright. To get at the TV brightness controls, I had to work my way through several menus, and it was a real distraction to do this during movies. When I finally got to the brightness control menu on the TV, I had four choices (1 through 4) from lightest to darkest. So, I assigned four macros to the "shifted" 1 through 4 keys. Each macro takes the TV to the appropriate menu, chooses the corresponding option, and then exits all of the menus. Now, I can easily and quickly adjust the brightness during DVD playback without having to pause the movie.

Ancillary Benefits

Because I had already done all the hard work, I decided to get a second remote for my stepson. In his room, he has a TV, VCR, satellite box, and DVD player. So, I bought him a (now defunct) RadioShack 15-2104 remote, which I found for only $10.00. It was easily JP1 programmable, so we set up all the codes, loaded the info into the computer, set up all the appropriate macros, and loaded the data back into the remote. Now, when my stepson borrows the batteries from either of the remotes, we'll be able to get everything back the way it was with just a few mouse clicks.

The Most Important Thing

My family likes the JP1 remote. The remote makes things simple enough for them to use our audio/video system without my intervention. Therefore, possibly for the first time, I actually achieved the ultimate goal of one of my re-wiring projects!

One Last Note

The experts in the JP1 group don't get paid, so if you'd like to explore this underground world, please try to read all the appropriate documentation before asking questions. The main docs to read are the JP1 FAQ (**www.hifi-remote.com/jp1/faq.shtml**), the Beginners Guide to JP1 (in the Help Documents folder at the JP1 Group), and the keymap master readme file (comes with the Keymap Master spreadsheet). **NV**

Michael Weingarden was a Systems Engineer on the Tomahawk Cruise Missile Project for nine years, and is currently a part-owner and Operations Manager for AgriZap, Inc., makers of the world's most sophisticated mouse trap – the Rat Zapper. In other words, he got bored being a rocket scientist and decided to build the better mousetrap.

Basics For Beginners

Just For Starters

Following the law — Ohm's Law, that is!

Last month, we looked at calculating the resistance of series and parallel resistors. Now, let's take a look at Ohm's Law and calculating current draw with the resulting heat dissipation.

Ohm's Law says that current is equal to voltage divided by the resistance. Or, current multiplied by resistance will give you the voltage. In other words, if you know any two of the factors, you can find the third. I always found it handy to use the circle version of this formula as shown in Figure 1. You can multiply the bottom to get the top. Or, you can divide either of the bottom ones into the top to get the other bottom figure. Look at the simple schematic in Figure 2. We have two resistors in parallel across a 10-volt source. Using Ohm's Law, we can see that the 10-ohm resistor will draw one ampere of current (10 volts divided by 10 ohms). The 10,000-ohm resistor will draw only .001 ampere, or one milliamp. At this point we need to change directions and see "What's Watt." First of all, a watt is a unit of power. Technically, one watt of power equals the work done in one second by one volt in moving one coulomb of charge. A coulomb is a unit that you never hear of. However, one coulomb per second is equal to one ampere. This you are familiar with.

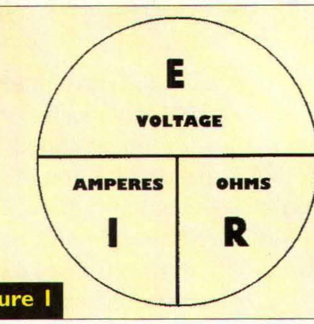


Figure 1

All this translates to saying that

power in watts is equal to the product of amperes times volts — or P = I x E. There are some variations to the formula, depending on the information you have available, that are used for specific situations. However, for our purposes here, we will settle for the basic formula. Going back to our earlier example, we found that the 10-ohm resistor would draw one ampere of current. Now, our wattage formula tells us that one ampere times 10 volts will give us 10 watts.

Therefore, the 10-ohm resistor must be at least a 12-watt resistor to keep from burning up. This is your 10 watts plus 20 percent. The wattage rating for the resistor needs to be — as a bare minimum — 20 percent more than the calculated draw. I usually try to give a 50 percent safety margin.

But, what about the 10,000 ohms? Here, Ohm's Law told us that the 10,000-ohm resistor will draw only .001 ampere. Then, our wattage formulas say that 10 volts multiplied by .001 ampere will give us .01 watt. A 1/8-watt resistor will stand .125 watts. Therefore, a 1/8-watt resistor would give us more than a 100 percent safety margin.

Now, let's look at a real-world situation around the house.

You have a coffee maker that says on its label it draws 1,200 watts. Then you acquire a microwave oven that says it draws 300 watts. You only have one outlet available and it is on a 20-amp breaker. Can you operate both of these at the same time? The labels give you the information in watts and we need to know how many amps. So, let's see.

We would have a combined draw of 1,500 watts when both machines are operating. We assume the house voltage is about 120 volts. Therefore, our wattage formula says that dividing the watts by the volts will give us our current draw; 1,500 divided by 120 gives us 12.5 amps. The answer is "Yes" you can operate both of them safely. Remember though, unless it is a dedicated outlet, it probably will

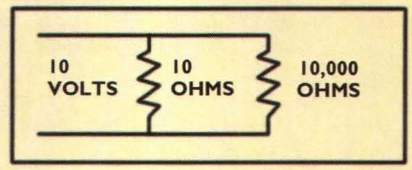


Figure 2

have other outlets and/or lighting on that same breaker and these would also have to be considered. Now, if you only had a 15-amp circuit, the surge current when turning one of them on could, very likely, trip your breaker even if it were a dedicated outlet. Always allow a reasonable safety margin. Particularly watch the wattage rating on extension cords. They are often quite a bit less than the outlet rating and will begin to burn before they will trip the breaker. Remember that house wiring is perfectly capable of killing you. Always turn off breakers and then use a meter or a voltage sensing pen before touching any wiring. **NV**

Micro Memories

Parts is Parts: High-Tech Surplus Stores From the 1970s to eBay

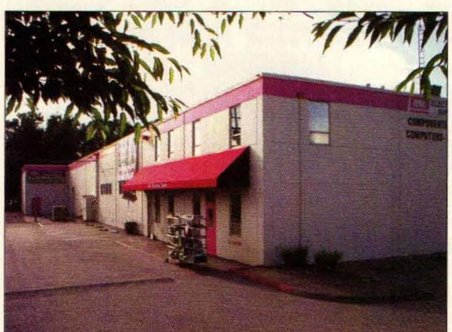
Return with us now to those thrilling days of yesteryear! Come with us as we roam those wild-west towns with bucolic names like Sunnyvale and Santa Clara. It's 1972 and the dot.com-internet high-tech bubble boom isn't even a gleam in Jeff Bezos' eye.

As we peer in the windows of the average home, we see ... well, we see no one is home. But the lights are on, and we hear music playing. Following the sounds of the music, we find that the inhabitants of this dwelling are in the garage. Ah, they must be participating in that most American of all hobbies — working on the family car. But no, there is no grease, and although messy, the garage appears ... could it really be ... it appears clean.

We have found the place of lore and legend — the Silicon Valley garage where companies like Hewlett Packard and Apple started. A place that has no rivals when it comes to high-tech nostalgia. Well, perhaps outside of Silicon Valley that's true. But there's another bit of nostalgia that's not as well known, but is at least as well loved — at least in memory. It's the surplus store.

The surplus store? You mean like an Army-Navy store? No, this bit of high-tech tradition is the electronics surplus store. Stores like Haltek and Halted, which in their heyday stocked literally hundreds of thousands of used, misused, misordered, and otherwise rejected electronic parts. Parts from the smallest diodes to complete pieces of manufacturing equipment. These stores — and there were many of them — not only in Silicon Valley but in Los Angeles, Seattle, and any place where large technology companies were located — were the source of parts, and in some cases, inspiration for many of the companies that became part of the high-tech boom.

Most were similarly laid out with long tables in the front, on which there were cardboard and plastic bins filled with parts, and larger equipment piled to the rafters in the back.



HSC Electronics Store.

A recent photograph of the Fry's in Fremont, CA. Orignially conceived of as a store for hardcore electronics buffs. These days, each Fry's store is a cross between a theme park and an electronics superstore.

The Two Steves Fail to Make Their Mark

As much as garages made it into the popular folklore of Silicon Valley, the surplus stores left their marks on the hearts of Silicon Valley's entrepreneurs. Robert Ellingson is the President of HSC Electronic Supply — better known as Halted — which has been serving Silicon Valley since 1963, when it was known as Halted Specialties Company. He says, "Somewhere I have a bill of sales — we sold a used oscilloscope to Steve Jobs back in 1975. The two of them came by once to sell the owner of the company some of their surplus junk when they needed money. He wasn't too impressed with barefoot guys driving around in an old VW van, with this crummy looking stuff that they were trying to unload. He says they even offered him at the time, 'Say, would you like a stake in our company?' They really needed money. And he said, 'No, I'll take a pass.' Nobody thought that people were going to have their own computer on their desk back then." Not only did the surplus stores provide a regular and convenient source of parts for building prototypes, but they provided inspiration, too.

The Birth of Fry's

Not quite a surplus store, but also a shop with some high-tech history is Fry's Electronics. Anyone who's been to a Fry's recently has seen a huge theme park-like store, with as many appliances as computer-oriented parts. But when it started in 1985, it was far from the store it is today. Back then, Fry's was a geek's dream store. In addition to chips, boards, cases, and other DIY parts, it carried Twinkies, cases of caffeinated sodas, heavily-illustrated pornographic magazines, and other essentials for the struggling entrepreneur or budding computer designer. It was open till midnight, and did not carry washing machines. My, how times have changed.

How Many Ideas Were Launched by Surplus Stores?

If you have the chance to speak with anyone who started a hardware-based high-tech business (or tried to) in the late 1960s through the 1980s, odds are they will look wistfully and regale you with stories of their own discoveries and adventures in the aisles of the surplus stores.

"I still get some of the Silicon Valley luminaries walking through here," Ellingson says. "The co-inventor of the microprocessor, Ted Hoff, still comes in a couple of times a year. I see Bob Pease in here every so often. He's been with National Semiconductor for years and years, and has written several books and writes a regular column on technology. I saw him in the store yesterday!

Plus, we get a huge turnover of fresh faces that are coming through in the middle of the day looking at all

Flooding the Zone: eBay Enters the Picture

So where do budding inventors and entrepreneurs get inexpensive parts now? Well, as we've seen, some of the old stores are still around. But you no longer need to live in an area of high-tech companies to buy surplus parts. Not only have some of the bricks and mortar stores gone online — such as Halted and Norton Sales (**www.halted.com** and **www.nortonsalesinc.com**, respectively) — but the big boy of reselling used things, eBay, (**www.ebay.com**) has entered the market. It isn't all that surprising, considering eBay's prior success online. The May 12, 2003 issue of *Fortune* magazine says, "One of the dot-com era's most remarkable success stories, eBay, now represents 2 percent of all the US e-commerce, and is one of the most significant technology companies created in the past 10 years."

Karl Wiley is the senior category manager for the business and industrial team at eBay. He says, "Our marketplace began as kind of a consumer-to-consumer marketplace, but over the course of the last several years, small and large businesses began to use it as a channel to sell products. In the last couple of years, we've seen a migration of small businesses within the eBay community begin to buy things on eBay for their business, as well."

In the past year or so, having spotted this trend, eBay has begun to put management resources around it in order to help grow this portion of their business.

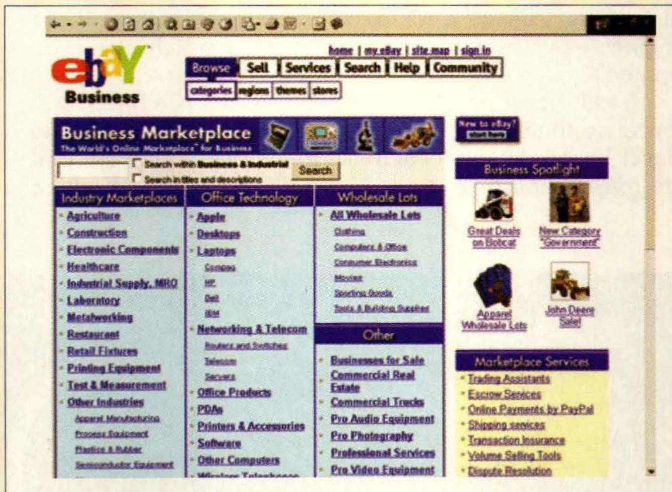
"One of the things that we've done recently," Wiley says, "is to launch a new 'front door' into eBay called **ebaybusiness.com**. It's basically a page that aggregates for our business buyers all of the business-related categories and services that we have on eBay."

There are three main categories — industrial and small business areas, "And then the third area," Wiley says, "is an area that we call Wholesale Lots. This is where small retailing businesses — many of whom are eBay sellers — are coming to eBay to actually source inventory by buying it in bulk across a variety of categories on the site — everything from sporting goods to consumer electronics and toys." One of the fastest growing categories in this section of eBay has been test and measurement equipment. Currently, Wiley says, "We're on our annual run rate to sell about 50 to 55 million dollars worth of equipment in that category. And that's grown about 75 percent over the last year. As you probably know, the test and measurement market in general has been relatively flat, so we're really thrilled that our own marketplace has been able to grow with that kind of relatively explosive growth.

If the bearded barefoot Woz and Jobs of 1975 looked at the quantity of equipment available in this section, they'd probably call it mind-blowing. "On any given day," Wiley says, "we've got slightly over 11,000 items for sale in the Test and Measurement categories, so selection is another one of the key ingredients, in addition to value. So, if I'm a hobbyist or a small entrepreneur, and I'm looking for a meter, there are over 1,900 available. If I'm looking for an oscilloscope, I can choose from 800 different ones, which is one of the advantages that we see versus going to your local used equipment dealer that may have 10 on the rack, and that's all you have to chose from."

The lineup typically includes a mixture of new and used equipment. "We obviously get a lot of surplus inventory and idle assets from companies," Wiley says. "One interesting example of that is Motorola, who has recently started selling some of their idle test and measurement equipment directly from their manufacturing facilities on eBay." Wiley says that the buyers of this type of equipment range "from individual hobbyists who are just passionate electrical engineers, ham radio operators, things like that — folks who are building stuff in their garages — to those folks who've kind of evolved into starting their own businesses to larger businesses, although they tend to be mostly still small — less than 100-employee businesses. And they can be small manufacturers, service shops, calibration labs, telecommunications consultants — folks like that, who need good serviceable equipment, they don't need the latest cutting edge technology straight from Agilent, or something like that."

While online sources such as eBay allow people far removed from Silicon Valley or the aerospace industry to find the parts necessary to tinker and invent, will online browsing have the same motivating effect as walking up and down aisles of parts? It's too soon to tell, of course. But it's clear that the tradition of using surplus parts in the high-tech field is long from dead.



eBay Business Home Page

eBay Home Page

the stuff," Ellingson adds. "You can tell a lot of them are repeat visitors, just because we keep putting new things out on the shelf, and a lot of people come in just to see what the latest and greatest is that we've dug up."

Down South: Need a Spare Titan II Rocket Engine?

As we said, Silicon Valley isn't the only source of surplus parts. Nick Kirchner is the president of Massively Parallel Instruments, Inc., who is on the cutting edge of ion processing technology. His company is located in Silicon Valley, but he says, "In my experience, the greatest of all surplus stores are in Southern California. I don't know which one I would have to say is the best, but certainly one of the best is Norton Sales of North Hollywood. You could go in there and buy anything — you could go in there and buy a caster for a bottom of a chassis, or you could buy some wires and a dial, or if that didn't suit you, and you wanted to get a couple of main engines off of a Titan II rocket, you can do it there. Not only do they have those engines — you could take your pick of which ones you wanted!

"I can never go in there with my wife," Kirchner says, "because there's all this stuff, and you just don't want to leave! There are spherical tanks made out of titanium that are maybe four or five feet in diameter. You could take a thousand PSI on those things, and yet you could pick them up with two fingers. Norton had so much stuff, Norton didn't even know what he had! Literally, you'd walk down these canyons filled with things.

"When I started going there in the '70s, Norton Sr. was running the place. He was this guy with a little dapper hat, a plaid jacket, and plaid bowtie," Kirchner says, "And he'd go to all these aerospace companies and buy all their stuff. Then his son took over, and now his grandson Chris is running the place. He's got so much stuff that it's supported three generations of people without any trouble. Norton Sr. would always joke that when he went to plumb his house, he plumbed it in Teflon-lined, high-pressure stainless steel tubing, that probably cost the government $100.00 a yard new, and now he's plumbed his entire house with it!"

Many of the surplus stores in Southern California, such as Norton Sales, started after World War II, selling war surplus equipment because Lockheed and all of those places were located nearby in Southern California, which in the 1960s, became the epicenter for many companies involved in the space program. "Probably now, you'll see a lot of electronics stuff in there, too" Kirchner adds. There is probably no way of measuring the impact of these stores on the growth of the high-tech industry. Certainly having easily-obtainable, used parts enabled experimentation and prototypes. But how many ideas, how many new ways of doing things were inspired by those parts in those little cardboard bins? We'll never know. **NV**

Electronics Showcase

Continued from Page 37

memory. All real-mode instructions are also available in virtual-8086 mode, though there are some differences in execution from that of the 8086. In short:

- Pentium instructions require fewer clock cycles than the 8086.
- CS:IP points to the DIV instruction, and not the following instruction, during an exception.
- Divide exceptions are not generated for IDIV quotients that equal 80H or 8000H.
- Undefined 8086 opcodes that represent valid Pentium instructions are executed and do not generate an invalid opcode exception.
- The value of the SP pushed with PUSH SP is the value before it is decremented, instead of the value after it is decremented.
- Shift/rotate counts are limited to 31 bits.
- The Pentium generates an exception if a data access or instruction fetch crosses the end of a segment (offset FFFFH).

• Bits 12 through 15 of the flag register contain different values. Bit 15 is clear, and bits 12 through 15 are set according to the NT and IOPL states. On the 8086, these bits were undefined.

These differences are slight, and should not interfere with the normal operation of programs originally written for the 8086. Virtual-8086 mode tasks always execute with a privilege level of three (the lowest), and may be entered/exited in a number of ways. A virtual-8086 task may be initiated by a task switch, which loads a new 32-bit TSS that has the VM bit set in its copy of the flag register.

Also, a procedure with a CPL of 0 (highest priority) may execute an IRET instruction that pops a one into the VM bit of the flag register. This indicates that the calling procedure was a virtual-8086 task, and causes the processor to re-enter virtual-8086 mode. To exit virtual-8086 mode, an interrupt or exception must be generated. If the interrupt or exception causes a task switch, the system may exit virtual-8086 mode if the new TSS is a 32-bit TSS, and its copy of the VM bit is clear, or if the new TSS is only a 16-bit TSS.

If the interrupt or exception calls a procedure with a priority of 0, the processor will also exit virtual-8086 mode. Figure 6 shows the possible ways to enter and leave virtual-8086 mode.

As Figure 6 shows, interrupts and exceptions cause the processor to switch between a virtual-8086 task and a virtual-8086 monitor task. The monitor task is itself a protected-mode task, and is responsible for initialization, interrupt and exception handling, and I/O for the running virtual-8086 task.

There may be literally hundreds or thousands of virtual-8086 tasks running simultaneously. Each requires the support of a monitor task. A handful of instructions will cause a general protection violation if executed in virtual-8086 mode with an IOPL less than three (recall that the CPL is always three in virtual-8086 mode). These instructions are CLI, STI, PUSHF, POPF, INT, and IRET. Intel calls these instructions sensitive instructions. Sensitive instructions may need special handling by the virtual-8086 monitor.

CONCLUSION

This three-part series provided many of the details and inner-workings of protected-mode hardware and software architecture. Only the surface has been scratched, for entire books have been written on this subject. Even so, this brief exposure should lead to an appreciation of what is going on behind the scenes, and as a stepping stone to greater study into this complex architecture. NV

"Where It Is and How to Get It"

Robotics Resources

Robotic "General Stores"

When I started robotics as a hobby, there was no such thing as a "robot store." The first I had ever seen was started in the mid 1980s by Timothy Knight, a young author who wrote a popular book on personal robots. His store, in the San Francisco Bay Area, offered for sale toys and robot kits. It closed a few years later, during the "robot doldrums," a sad period when amateur robotics was on the decline because of lack of decent hardware.

Now, with sophisticated microcontrollers costing less than a night at the movies for a family of four, there's plenty of interesting products to sell, and robotics specialty stores have cropped up all over the world. A few are local retail stores only, but most offer mail order sales through catalogs or the Internet.

Robotics specialty stores — the "general stores" of the robotics world — stock a variety of items, from robot toys to kits, sensors, motors, and microcontrollers. The sources listed in this month's column expressly concentrate on amateur robots, and all will sell mail order (many internationally). I selected those firms that offer at least some variety of product, and not just one or two robotic kits or microcontrollers that happen to be useful in robotics. These product lines have been covered in previous columns, and will be the subject of future columns.

Acroname, Inc.
4894 Sterling Drive
Boulder, CO 80301-2350
www.acroname.com

Acroname is an online retailer specializing in robotics. They carry numerous kits and robot parts, including:

- CMU Camera Kit — Low-cost robotics vision.
- LEGO Mindstorms — The latest versions.
- Handy Board Kit — Microcontroller designed expressly for robotics.
- PalmIII PPRK — Build a bot with your Palm Pilot.
- Rug Warrior — Popular intermediate robot from the book *Mobile Robots.*
- Omniwheels — Used in the PPRK and as casters.

The company also sells numerous (and some hard-to-find) sensors: ultrasonic, infrared (including the Sharp infrared distance and proximity), and flame, as well as the OOPic and BASIC Stamp microcontrollers. An extensive array of online documentation, gallery of customer's robots, and datasheets round out this excellent resource.

Blue Point Engineering
213 Pikes Peak Place
Longmont, CO 80501-3033
www.bpesolutions.com

Says the web site, "One of the main goals of Blue Point Engineering is to provide a product line of low cost, high quality software, hardware, electronics, and supplies used in animatronics, robotics, haunted industry, and technology education, for hobbyist and professional designers, imagineers, and dreamers creating their own forms of animatronic and robotic life."

Budget Robotics
P.O. Box 5821
Oceanside, CA 92056
www.budgetrobotics.com

Budget Robotics (my company) emphasizes structural elements, such as robot kits, platforms, bodies, and frames. Additional products include:

- Low-cost metal framing components.
- Precision-cut robot bases, in different colors and shapes, to make unusual robot bodies.
- Omnidirectional wheels, in a variety of sizes and styles.
- DC gearmotors and gearmotor kits.
- Robot Parts Play kits — assortment of useful small robots for robot building.
- Spherical casters (these aren't ball transfers, and are quite unique).
- Specialty fasteners (lots of nylon pieces), hardware (like hex spacers), and more.

Competition-Robotics
P.O. Box 1178
Swindon
SN25 4ZL UK
www.competition-robotics.com

Sells robot kits, sensors, and microcontrollers for small robots, with an emphasis on sumo and similar competitive robot games.

Future-Bot Components
203 N. Pennock Lane
Jupiter, FL 33458
www.futurebots.com

Future-Bot sells numerous robot, electronic, and mechanical parts. Products offered include: Motorola-based microcontrollers, gear motors, plastic domes, tilt switches and other sensors, ICs (various), recycled computer parts, and more.

HVW Technologies, Inc.
3907-3A St. N.E. Unit 218
Calgary, AB
T2E 6S7 Canada
www.hvwtech.com

HVW Tech is a leading online Canadian retailer of robotics, microcontrollers, and related products. They ship internationally. The product mix is varied and includes:

- Books.
- Development tools — PIC programmers and prototyping boards.
- Displays — LCD serial interface and video-text overlay.
- Educational tools — BOE-Bot robotics kit and Stamps in Class.
- Microcontrollers — BASIC Stamp, OOPic, PICmicro, and 68HC11.
- Misc. components — High current driver chips and serial EEPROMs.
- Robotics — Cybug robotic kits, motor controllers, motors and wheels, motorized gearsets (Tamiya), servos, and controllers.
- Sensors — Infrared and temperature.
- Software — Compilers for PICmicros (BASIC, C).
- Radio frequency — 2.4 GHz Wireless Video Transceiver.
- Static control.
- Sharp infrared distance and proximity sensors.

Images SI, Inc.
39 Seneca Loop

Staten Island, NY 10314
www.imagesco.com

Images SI, Inc. (operated by book author John Iovine) offers a wide range of high-tech goodies well suited to robotics. John has an eye for the special, and he's often one of the first retailers to offer a new technology. Among the products carried by Images SI, Inc. are air muscles, Nitinol shape memory alloy, robot hardware, wheels (including omni-directional), motors, gearboxes, plastic domes, flex and pressure sensors, assorted semiconductors and parts, and more.

JCM Inventures/JCM Electronic Services

3335 Caribou Dr. N.W.
Calgary, AB
T2L 0S4 Canada
www.jcminventures.com

JCM makes and distributes the Cybug and BEAM robot kit with a decided buggy appearance. They also sell a sound generator board, programmers, spare parts, and a popular H-bridge motor driver printed circuit board based on the L298 driver IC.

Kronos Robotics

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

Kronos sells parts and kits for amateur robotics. They offer their own line of microcontrollers and support electronics, as well as sell various robotics components, such as the Tamiya Educational gear motor kits. R/C servo motors, wheels, ICs, and other electronics. The site offers numerous articles, with circuit diagrams and construction details.

Lynxmotion, Inc.

P.O. Box 818
Pekin, IL 61555-0818
www.lynxmotion.com

Lynxmotion sells high-quality kits and parts for mobile robots — both wheeled and legged — as well as robotic arm trainers. Their plastic robot kits include four- and six-legged walkers, which come complete with servo motors, linkages, and other hardware. Most kits are available with or without processors, and you can add sensors as you wish.

MarkIII Robot Store

www.junun.org/MarkIII/Store.jsp

The Mark III is a mini sumo robot designed by members of the Portland Area Robotics Society (PARTS). It's available in kit form from several mail order resources. The **junun.org** site is the primary seller of this low-cost kit. The kit itself is available ($92.00, with microcontroller), as well as various components, such as accelerometer kits, Sharp infrared sensors, R/C servo motors, wheels, microcontrollers, and microcontroller programmers.

Milford Instruments, Ltd.

Milford House
120 High Street
South Milford Leeds
LS25 5AQ UK
www.milinst.com

Milford sells robot and mechatronic goodies through the mail. Their products include BASIC Stamps and accessories, LCDs, robotics, animatronics, and PIC stuff.

Mondo-tronics, Inc./Robot Store

124 Paul Drive, Suite 12
San Rafael, CA 94903
www.robotstore.com

The Robot Store sells all kinds of robotics goodies, from kits to books to individual parts (like motors, sensors, and wheels). Carries LEGO Mindstorms, Parallax BASIC Stamp and BOE-Bot, Sony AIBO Robot Dog, servos, servo controllers and motor drivers, batteries and chargers, speech recognition modules, and more.

Mr. Robot

10220 Robious Road
Richmond, VA 23235
www.mrrobot.com

Mr. Robot specializes in robots, parts, and supplies (sorry, there is no Mrs. Robot). Products include microcontroller kits, robot kits, servos, DC gearhead motors, infrared and ultrasonic sensors, wireless mini color camera, Fischertechnik construction kits, and omni-directional wheels (omniwheels).

Parallax, Inc.

599 Menlo Drive, Suite 100
Rocklin, CA 95765
www.parallax.com

Parallax is perhaps best known for its BASIC Stamp microcontroller, but they also offer a variety of robotics kits and components. Two of their most popular kits are the Boe-Bot and the Toddler. Both use R/C servo motors for propulsion. Their "components store" lists a variety of odds-and-ends you can use in redesigning your Boe-Bot or Toddler, or in your robotics creations.

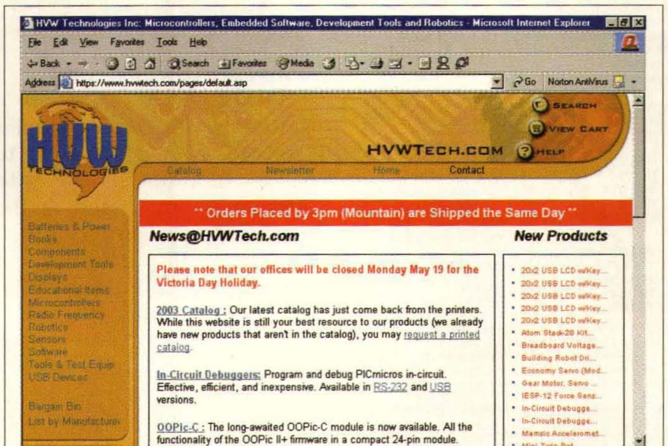


Figure 1. HVW Tech in Canada, ships worldwide and offers a wide assortment of robot kits and parts.

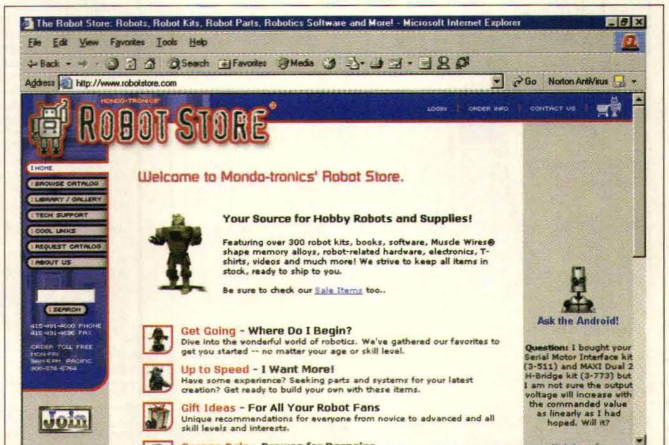


Figure 2. Robot Store's large variety of goodies make them an ideal source for your robot buying needs.

The company sells R/C servos that have already been modified for continuous rotation, uniroller balls for use as casters, various hardware, wheels, and more.

Pitsco
P.O. Box 1708
Pittsburg, KS 66762
www.pitsco.com

Pitsco is primarily a source for schools, teachers, and other educators to purchase mechanical components for science classes and experiments. They offer a wide variety of kits and components. Online shopping is available through their ecommerce portal, **www.shop-pitsco.com**.

- Brutus robotic arm.
- Pitsco Blinky robot kit.
- Sensor kits and software.
- S-Cargo and other OWI robots.
- Space Wings electronics kit (shape memory alloy).
- R/C servos.
- Servo power transmission (hub mounts, sprockets, sprocket chain, gears, wheels).
- Plastic injection molding tools and supplies.
- Plastic vacuum forming tools and supplies.
- Aircraft birch plywood.

Though expensive, they have foam wheels with servo mounts so they can be directly attached to an R/C servo without any extra hassle.

Also see **www.pitsco-legodacta.com/.**

Robologic
134B Listerhills Rd.
Bradford
West Yorkshire
BD7 1JR UK
www.robologic.co.uk

UK-based retailer of robotics equipment. They offer microcontrollers (including the BasicX from NetMedia), infrared sensors, and motors. They also provide tutorials on robot building.

Robot Store (HK)
7th Floor, Fok Wa Mansion
No.19 Kin Wah St.
North Point
Hong Kong
www.robotstorehk.com

Robot Store (HK) is a robotics mail order retailer based out of Hong Kong. Not to be confused with RobotStore.com, based in the United States.

Robot Store (HK) is an authorized distributor of the MIT Handy Board microcontroller and expansion board developed by Dr. Fred Martin of the Massachusetts Institute of Technology (MIT) Media Lab. They also offer the licensed Interactive-C development tool developed by Newton Research Labs. The company sells assembled and unassembled

Circle #127 on the Reader Service Card.

Circle #125 on Reader Service Card.

Circle #128 on the Reader Service Card.

MIT Handy Board systems, robot bases, sensors, gear box kits (from the Tamiya Educational line), servos, DC motors, and various mechanical parts.

RoboToys
12025 Ventura Boulevard
Studio City, CA 91604
www.RoboToys.com

According to the site, "We carry a variety of robot toys, educational scientific kits, classic robots, robot construction kits, Gundam and anime model kits, tin windup robots, Giant Robot anime videos, and more!"

The site provides a user-to-user forum for robonuts to chat about whatever is on their minds.

RobotOz
P.O. Box 635
Inglewood, WA 96932
www.robotoz.com.au

Robotics down under. (Don't forget the .au at the end of the URL.) RobotOz is a reseller of:

- Lynxmotion products.
- Parallax, Inc. BASIC Stamp microcontrollers.
- Muscle Wire shape memory alloy.

They also sell various BEAM kits, as well as the Handy Board microcontroller from **RobotStoreHK.com**. On-site tutorials include "Make your own BEAM Photovore," with step-by-step directions and pictures. You'll also find user-to-user forums and robotics links to fill out your day.

Solarbotics, Ltd.
179 Harvest Glen Way N.E.
Calgary, AB
T3K 4J4 Canada
www.solarbotics.com

Solarbotics is a primary retailer of BEAM robots — both in kit and ready-made form. BEAM robotics was invented by Mark Tilden in 1989, and following a "simple is better" approach to design. Though simple, many BEAM robots are actually quite sophisticated in their function. Products include various light-attracted bugs and walking robot kits, motors, solar cells, and electronics. The Solarbotics site also provides articles on BEAM, a gallery of BEAM robots built by others, and links to other important BEAM sites. Also check out **www.solarbotics.net/** for more BEAM resources.

Tech-supplies.co.uk
Revolution Education Ltd.
4 Old Dairy Business Centre
Melcombe Rd.
Bath
BA2 3LR UK
www.tech-supplies.co.uk

Says the site, "The new online shop for all your electronic, robotic, and educational technology projects. The site provides a comprehensive one-stop shop for students and hobbyists looking for resources for electronic and robotic projects."

Products include:

- Robot kits — OWI robots and LEGO Mindstorms.
- PIC and BASIC Stamp microcontrollers and programmers.
- Modeling materials — corrugated plastic and metal sheets.
- Motors and servos.
- Electronic components — LEDs, light sensors, and H-bridge motor driver chips.
- Tools.

Total Robots, Ltd.
Global House
Ashley Avenue
Epsom, Surrey
KT18 5AD UK
www.totalrobots.com

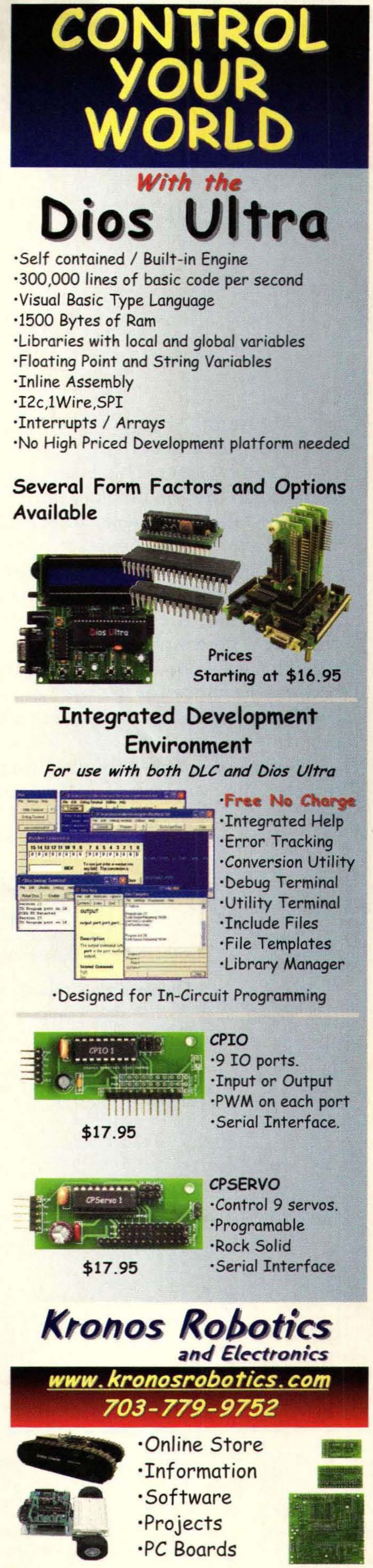
Reseller of the OOPic microcontroller, several BEAM robot kits, various robot kits from Lynxmotion, the ARobot from Arrick Robotics and, of course, robotics components (motors, GPS modules, microcontrollers, wheels, and much more).

Zagros Robotics
P.O. Box 460342
St. Louis, MO 63146-7342
www.zagrosrobotics.com

The main product line at Zagros is robotics bases, which include the plastic base plate of the robot and two motors. They also offer electronics components:

- Sensors — Polaroid 6500 ultrasonic ranger, Dinsmore digital compass, and Sharp GP2D02 infrared.
- Computers — Eyebot Controller, HC11 MC processor with backplane, and 386 Single Board Computer.
- Miscellaneous — H-bridge ICs, 300MHz RF remote control, and DC gearmotors. **NV**

Gordon McComb can be reached at **www.budgetrobotics.com/.**



Exploring and Experimenting With Lasers and Their Properties

Laser Insight

Construction of a Cr:Ruby laser continued ...

Last month, I began describing the construction of a simple Cr:Ruby laser. This issue, I will try to finish the mechanical parts of the laser head, and begin to assemble the optical rail. The description I give will be based on using an optical bench plate from Edmund Scientific, and the machined parts described here and last issue. You should base your assembly on the option you chose for the optical rail and laser head, as discussed last month.

Before we begin though, I must restate the warning I gave last month.

This laser is dangerous. The power supply is capable of producing lethal voltages, and at very high pulsed current capacity. This is a serious laser, and should only be undertaken by those persons who will take it seriously. The capacitors used in the supply will retain a high voltage charge for a long time, and must be completely discharged before any work is done inside the unit.

If a short circuit occurs during the discharge of the high voltage capacitors, then serious damage to the supply will result, as well as anything else that may be attached to the supply. I have seen heavy current wire disintegrated (with a very loud *bang*!) by these supplies, and I have heard that a capacitor once blew out four cinder blocks from a wall under a fault condition. It is a very powerful supply, and should be built carefully, with regard for safety being the top priority. There will be a number of safety interlocks built in to the power supply and laser rail, and these devices must be incorporated to ensure safe operation of the laser. *Do not omit or bypass any of these interlocks!!*

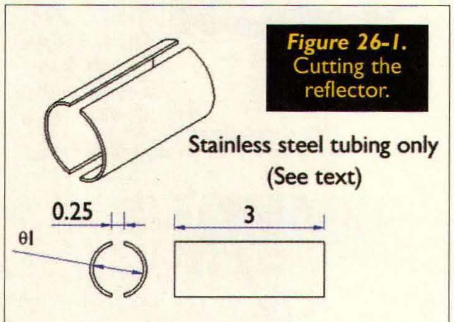


Figure 26-1. Cutting the reflector.

In last month's issue, I gave details of the laser head and top cover, and showed a final assembly drawing with all the components that go into the head. All of the components to be described in this issue should be made of 304 or 316L stainless steel. Stainless steel has a very low tendency to leach ions into the water, whereas copper and its alloys would allow the water to become conductive over a period of time, and must be avoided. Hence, the warning in the last issue.

Turning now to the drawings of the various parts; there is nothing critical about the dimensions of most of these parts, and a tolerance of ± 0.005-inch should be okay. The most difficult parts to make here are the laser rod holders (seen in Figure 26-4), so let's describe them first.

You can use 1/2-inch nominal diameter bar for these parts, and take a skim cut to reduce the diameter to exactly 1/2 inch. Drill the thru-hole before you cut the thread, in case the drill wanders and ruins the part. Open the hole to 0.350-inch to the depth specified. Ream out the 1/4-inch hole with a 10-20 mil oversize reamer. This will minimize the clearance between the rod and the holder to prevent misalignment of the rod, and minimize the possibility of water leakage.

The thread is a light cut and will not subject the drilled tube to a lot of undue force. Set the lathe up to make a very light cut at each pass to get a clean thread. The threaded end cap is used to compress the Teflon "O" ring (Parker #2-010, Teflon) around the rod, and should be made so that the cap bottoms out on the tube when assembled

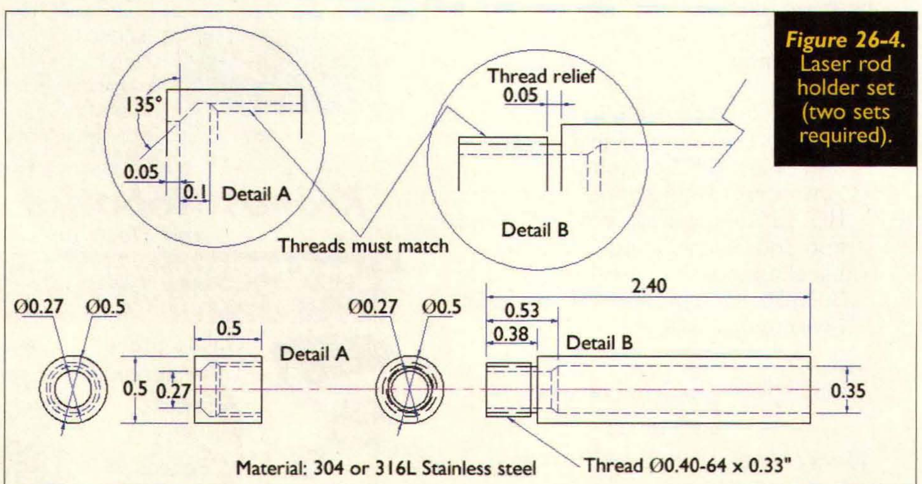


Figure 26-4. Laser rod holder set (two sets required).

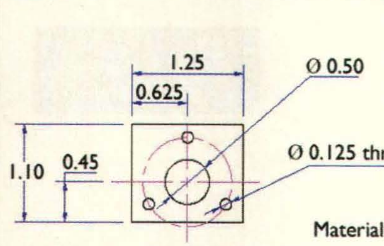


Figure 26-5. Laser rod seal plate (two required).

without the "O" ring in place.

The threads should be an easy fit, and the inside chamfer smooth to apply uniform pressure around the "O" ring, and avoid putting undue stress on the rod. Be careful to remove all burrs around the location of the "O" ring to avoid any cuts. A leak on the seal by the end of the rod would allow water to seep over the rod face, destroying laser action, and possibly damaging the rod.

The reflector halves (Figure 26-1) can be made from a piece of stainless steel tubing about 1mm (0.04 inch) wall thickness. The thickness is not critical, so long as the piece does not distort when cut on a milling machine, nor interfere with the lamp or rod when installed in the head.

When cutting the reflector, you may want to support it by inserting a piece of broomstick on the right size. This will allow you to grip the tube better without too much distortion. Use a 1/4-inch end mill to cut the tube along its length, then flip it over and repeat the cut, so you finish up with two halves of equal size.

When placed together in the head block, the two halves form a near ellipse. You must then remove any machining burrs, and carefully polish the two halves to get a mirror-like finish all over the inside surface of the two parts.

The overall efficiency of the laser is dependent on getting all the light from the flashlamp to focus into the rod, so you should aim to get as high a polish on the reflector halves as you can.

The lamp clip blocks (Figure 26-2) are used to carry the high discharge current from the capacitor into the lamp, via nickel-plated fuse clips. Again, the dimensions are not super critical, and a tolerance of ±0.005 inch is quite acceptable.

Drill two sets of threaded holes for the lamp clip, and you can experiment with different lamps in the same head. Cut the chamfers on the end of the block to clear the round corner in the plastic head block. You'll note that the threaded hole in the side for the lamp connector does not go through the center of the lamp clip block.

When you assemble the head, make sure the block is oriented correctly, or the lamp will sit too high between the reflector halves. Use #2-56 x 1/4-inch screws to hold the clips to the block.

Make sure the screws are tight. Any arcing here will rapidly erode the clips or the block and form oxide films that act as insulators, thereby forcing the arc to take a longer path each time the laser fires. Thus, the problem quickly worsens until the lamp clips are burnt through and have to be changed. If this happens, you will have to machine the surface of the blocks to remove the oxide film.

Figure 26-3 shows the high voltage connectors for the laser. These are, again, stainless steel to avoid any problems with electrolytic action through dissimilar metals being in contact.

When these are installed, a small "O" ring (Parker #2-007) slips over the plain part of the threaded shaft to seal against the inside of the hole in the block. Smear a thin layer of silicon grease over the "O" ring before assembly, and the "O" ring will not be cut. The two flats machined into the large diameter are for a wrench to tighten the connectors. Be careful not to overtighten them, or the "O" ring may be damaged.

The internal thread is for a #10-32 screw to connect the HV cable from the supply. When connecting the wires, use a wrench on the flats of the connectors to prevent them from turning.

The rod seal plate in Figure 26-5 compresses an "O" ring around the outboard end of the rod holder to form a water seal. The three screws apply uniform pressure around the "O" ring, and force the ring into the chamfer machined on the end of the head block.

Thus, the compression is both lateral into the block and concentric around the rod holder. The seal plate is held to the head block by three #6-32 x 1/2-inch screws.

Again, resist the temptation to overtighten any screws going into the plastic block. For one thing, it isn't necessary, and for another, the threads in the block can be easily stripped by the overzealous use of the screwdriver.

Laser head assembly

Mount the laser head bottom block onto the optical rail using 1/4-inch-20 x two-inch screws as indicated in the assembly drawing.

Begin assembling the head by placing the lamp clip bases, with clips attached, into the lamp cavity.

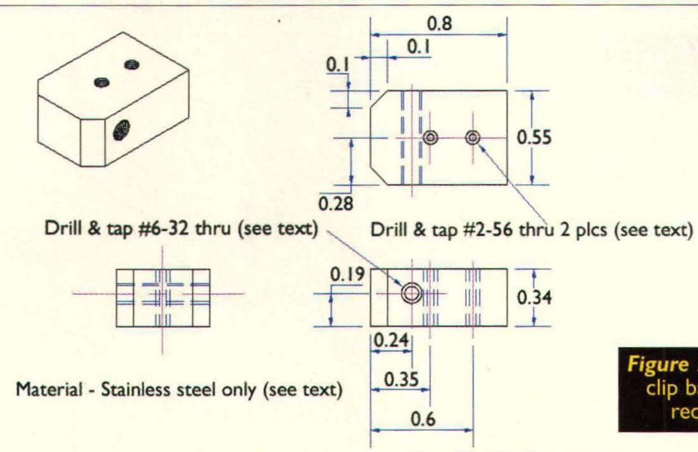


Figure 26-2. Lamp clip bases (two required).

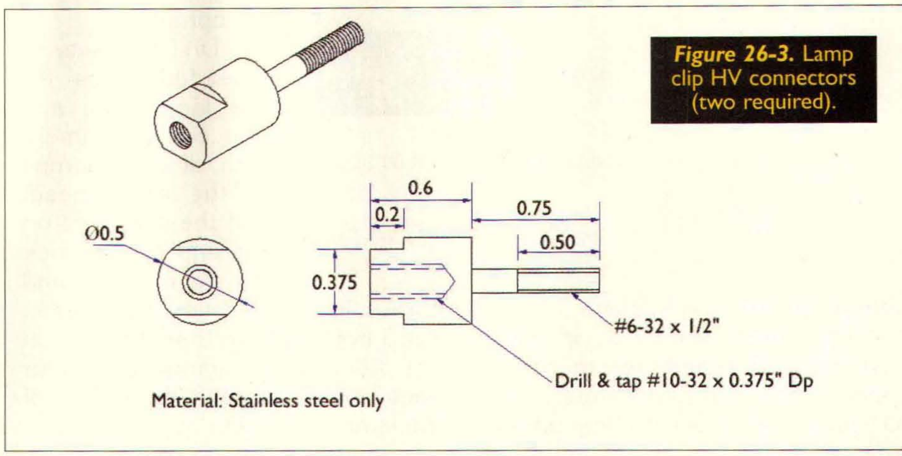


Figure 26-3. Lamp clip HV connectors (two required).

Place an "O" ring around the plain part of the high voltage connector with a small amount of silicon grease smeared over it. This will aid in lubricating the "O" ring while it is compressed, and fill any small voids or scratches left by the machining process. Insert the HV connectors in the head and tighten by hand. Tighten about half of a turn more using a wrench.

Insert the two water fittings on the opposite side of the head, using Teflon tape to aid in tightening and to fill any scratches or voids.

To mount the laser rod, you'll have to make a special stand to hold everything in alignment. It is important that the rod be concentric and collinear with the rod holders, otherwise an unnecessary sideways strain will be imparted to the rod, which may cause early failure.

Details of the fixture are given in Figure 26-6. I did not include many dimensions for this item because they are not critical, and any scrap aluminum block would suffice. The main thing to remember with this fixture is that the two "V" channels must align properly or the rod may be damaged.

The aluminum baseplate for the fixture should be about eight inches long and about four inches wide by 1/4-inch-1/2-inch thick — flat and smooth.

The "V" blocks are made of aluminum and are placed in the milling vice together when grooving. This ensures that the two grooves are exactly aligned and equal in height. Fix the two blocks loosely to the base plate using #10-32 screws, and loosely fit the upper "V" grooved parts to the blocks using #8-32 screws.

Use a straight steel rod 1/2 inch in diameter to align the two blocks, by placing the rod between the clamps and tightening the clamps using the #8 screws. When the rod is held firmly, tighten the two #10-32 screws holding the block to the plate. Tighten these screws well. Remove the steel rod and the two "V" blocks should be in perfect alignment.

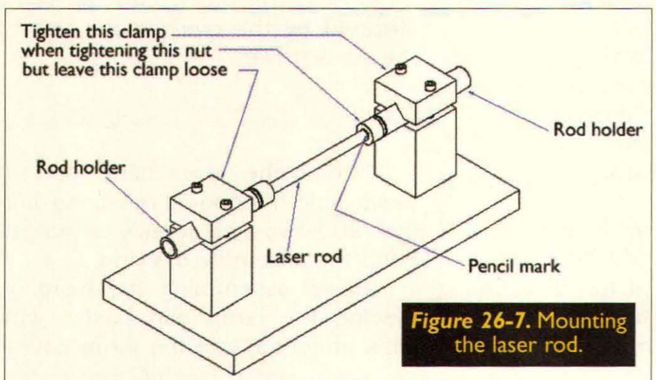
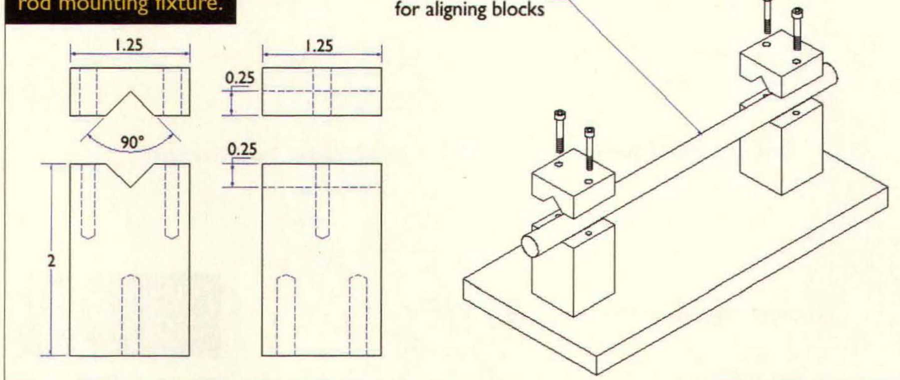


Figure 26-7. Mounting the laser rod.

Figure 26-6. Laser rod mounting fixture.



Mounting the laser rod

To use the rod mounting fixture described above, place one of the stainless steel rod holders in one clamp and tighten it down using the #8-32 screws. Allow approximately 3/4 inch of the holder to stick out as shown in Figure 26-7. Make sure this clamp is tight, and does not rotate when the rod holder nut is tightened.

The other rod holder assembly may be inserted into the other clamp, with the "O" ring and end cap installed, but should be left loose at this stage. Make a small pencil mark on the laser rod, approximately 3/16 inch from each end. The pencil marks will be used as a guide when installing the rod in the holders.

Take care not to touch the ends of the rod, and preferably, when doing any work with rods or optics in general, wear some powder-free latex gloves or finger cots to avoid any fingerprints or sweat getting onto the delicate coatings. Place an "O" ring (Parker #2-010) into the rod holder nut and carefully screw it onto the holder. Leave it loose so the rod may be slid into the "O" ring without undue pressure.

Hold the rod carefully, and gently insert one end of the rod into the holder with the "O" ring, using a twisting motion as you do so.

As you push the rod in, note the resistance offered by the "O" ring. Avoid touching the rod holder on the end of the rod, as this could scratch the surface. Tighten the rod nut a little, and see if the resistance to insertion increases. Push the rod in until the pencil mark is flush with the outside surface of the rod nut. Tighten the nut by hand.

Align the other rod holder to the opposite end of the rod, and carefully adjust the rod holder to insert the rod. Tighten the second clamp finger-tight only. This will align the rod correctly to the first rod holder.

Use rubber-faced pliers to tighten the first nut an additional half turn. You'll notice that as you do this, the rod will turn with the nut. Because of the tendency for the rod to twist, it is essential that only one clamp is tight around the rod holders at any time.

The rod will be easily damaged beyond repair (remember ... $1,700.00) if unnecessary torque is applied to it.

When one end of the rod is secured, loosen the clamp holding that end. Tighten the clamp on the other end, and withdraw the rod until the second pencil mark just shows. Tighten the rod nut by hand as above. Use the rubber-faced pliers to tighten the nut an additional half turn.

When both ends of the rod are secured, loosen all clamp screws and carefully withdraw the rod assembly from the fixture. Place it somewhere it cannot fall or roll.

Place one of the reflector halves in the head as indicated in the assembly drawing. Carefully insert the rod assembly through the hole in one end of the head, and guide it through until the rod holder is seen emerging from the hole in the other end of the head.

Apply a thin smear of silicon grease to two "O" rings (Parker #2-112) and install one on each rod holder as it emerges from the head block. Put the rod holder seal plates over the ends of the rod holders and, after carefully centering the rod assembly in the head block, secure them with #6-32 x 1/2-inch screws, as indicated in the assembly drawing.

Install the flashlamp into the lamp clips, and place the second reflector half on top. Place the top cover into position and secure it with six #8-32 screws as indicated in the assembly drawing. This should then complete the laser head assembly.

Next issue, we'll finish the assembly of the optical rail, and start to discuss the cooling system.

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. It sometimes takes a while to answer all my emails, but bear with me, I always reply. **NV**

The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Fooling Yourself

Engineers often work at the leading edge of science and technology. This means that new and unusual observations occur with some regularity. Unfortunately, sometimes these observations turn into fanciful ideas that are simply wrong. This article will show ways that may stop you from fooling yourself.

Silly Ideas Abound

There are loads of silly ideas in the world today. And, by "silly" I mean "refuted by unbiased observations." Some are very important. For example, it wasn't too long ago that the CEOs of all the major cigarette companies testified, under oath and on TV, to a US Senate committee, that cigarettes didn't cause cancer. Less important are the advertisements for knee wraps that contain magnets to aid in healing.

These two examples were chosen to show that money can affect people's perception. It is not unreasonable to say that the CEOs actually believed their statements. In the same way, the people who sell the magnetic knee wraps may very well believe that their product works effectively.

What's more, there are many people who use these wraps that swear these wraps have helped their knees. Why?

The reason is simple human nature. If there is a personal advantage for you to believe something, you will tend to believe that thing. In this case, the advantage is obvious — it's money. The CEOs are concerned with their multi-billion dollar industry. The magnetic wrap manufacturer's company is important to him, too. And the person who buys a wrap doesn't want to admit that it was a waste of $29.95. Or, quite likely, the knee got better by itself.

In these instances, the people involved simply ignore common sense and evidence that refutes their position. This is because they have an incentive to do so. Conversely, taking a more conventional position would be a disadvantage to them.

Fame as an Incentive

Money is a clear incentive to believe something. But, there are other incentives, as well. For engineers, one incentive is notoriety. Everyone wants to be famous. Discovering something new is one way to achieve that. But, this incentive can be insidious and difficult to spot.

For example, shortly after Roentgen discovered X-rays, the well-known French physicist Rene Blondlot claimed to have discovered a new type of radiation that he called "N-rays." These rays were said to emanate from all things except green wood. They could only be detected by a calcium sulfide thread that was supposed to glow very dimly after passing through complicated apparatus that contained a special aluminum prism.

The scientific community tried to replicate these unusual findings. Some researchers could and some couldn't. What's more, the basic idea of N-rays didn't seem to make sense. Of course, new observations don't always fit into conventional theories. Nevertheless, there were those that were skeptical.

One of these was Robert Wood, who managed to be invited into Blondlot's laboratory to observe some experiments. Wood, while examining the apparatus, secretly (and quite unprofessionally!) removed the vital aluminum prism before the experiments took place.

Surprisingly, this had no effect on the results. Blondlot could still "detect" N-rays even though the apparatus was disabled. Obviously, when these experimental results were publicized by Wood, the reality of N-rays evaporated.

More recently, a very similar event has occurred. I am referring to cold fusion by Fleischmann and Pons. These scientists really believed in their observations. Others even claimed to have reproduced them. But, unfortunately, cold fusion simply isn't real.

It turns out that the "simple" measurements of heat generation are not as simple as first believed. Simplistically, their apparatus absorbed heat somewhat like a capacitor stores an electric charge. They measured the discharge, but didn't take into account all of the heat previously and unwittingly applied to it. Like an unknown trickle charge on a capacitor, the discharge appeared to be greater than the deliberately supplied charge.

Noise Patterns

Noise is always a concern in measurements. Worst of all, noise can be thought of as a combination of all possible patterns. This means that if you look hard enough for something in plain ordinary noise, you'll probably find it. Trying to glean information from background noise is a never-ending problem.

A classic noise example is the Martian canals. In 1877, Italian astronomer Giovanni Schiaparelli reported that he could see "canali" or "channels" on the surface of Mars. The word canali was later corrupted to canals. The famous American astronomer, Percival Lowell, built the largest telescope of the time and also claimed to see canals. He zealously studied Mars and drew detailed maps of the canals that stretched from Martian pole to pole.

The idea of canals did not seem to lessen when others couldn't see them. Even when more powerful telescopes were built and failed to show canals, Martian canals were still believed to exist. It wasn't until 1964 when the NASA Mariner space probes proved conclusively that canals weren't there that this idea finally died.

This idea lasted about 90 years because one astronomer created a fanciful idea based on noise. He tried to gather information beyond the resolution of his telescope and his eyes. The result was nothing more than wishful thinking. (The Martian face is another example of a noise pattern.)

Third-Party Hoaxes

There are always some people who delight in mischief making. In particular, there are those who target the scientific community. Sometimes, these people find satisfaction in making important people look silly. Other times, they simply like the challenge of outwitting the intellectual establishment.

Probably the best example of this class is crop circles. They seemed to have reached a peak in popularity. There are movies and TV shows and books all attributing special powers or extraterrestrial origins or some other paranormal characteristic to these patterns in the fields. There are even serious researchers who call themselves "cerealogists" who study the patterns in detail.

While some of these may suggest that occult forces are at work, others look for a natural explanation — like peculiar wind patterns or animal behavior or the like. However, unbiased observation says that these patterns are made by ordinary people using commonplace materials. The evidence is absolutely clear in this respect. Crop circles are made by human beings.

What is the evidence? First of all, some of the people have admitted to making the circles. Second, they told how they did it. Third, they showed the tools they used. Fourth, they detailed the methods they used to make the designs. Fifth, the physical evidence in the fields matches the tools they described. Finally, they actually videotaped themselves making a complex crop pattern in a field in one night. There is absolutely no doubt to any unbiased observer that a few people can produce a complex crop circle in one night using simple tools. (There is a three-hour film called "Circle Makers" that details this.)

What's more, these same people speak of a community of "Plankers" who compete with each other to make the most intricate patterns. It seems that crop circles is becoming a new form of artistic expression.

But, even with this evidence, there are those who say that some crop circles are still made by aliens from outer space. They say that there is a difference between "real" crop circles and those made by humans. Why? Probably because they have spent so much time and effort studying them that it would be devastating to admit how wrong they were. That's just human nature.

And, here is a parallel to the tobacco CEOs that I discussed earlier. I said that it was not unreasonable to think that they believed what they said. I suspect many readers took exception to that.

But, what of the cerealogists? It seems clear that they believe even in the face of overwhelming unbiased evidence against them. The point I'm trying to make here is that fooling yourself can occur even in the face of the most extreme evidence to the contrary.

Understanding versus Believing

Probably the first thing to do when you find an unusual or unexpected result is to replicate it. Can you make that result happen again? Can you always make it happen? Make small changes and see what happens. Document your results in detail. This is important! Note every dial setting, voltage level, and anything else that could possibly have an effect.

A photograph of the apparatus is a good idea (but, by itself, isn't enough). I've had situations where the humidity was important and also when a test lead wire placement was

FEEDBACK

How am I doing? I'm always interested in feedback of any sort from readers. If there is a specific topic you'd like me to address or a specific problem that may be of interest to others, please let me know by contacting *Nuts & Volts* at **editor@nutsvolts.com**.

critical. This is the first step in understanding or learning about the observation. And this is the most important thing. You must learn and understand what you are seeing. This cannot be stressed enough. Understand fully what you see before you start to interpret.

Once you start to interpret, that is, once you start explaining, you start to believe. And once you believe, you stop searching because you think you have the answer. Like the old joke — you always find the lost keys in the last place you look. This is just human nature.

Keep an open mind and collect all the data you can. It's often better to identify what the observations *can't* be, rather than suggesting what they might be. The reason for this approach is quite simple. There are specific reasons why things can't be something.

However, only your imagination limits what might be. This is how silly ideas get their root. And, as we've seen above, once they get rooted, they're hard to remove.

Note that this is different from the "Scientific Method" where a theory is presented and data is collected to support or refute the theory. This is because there isn't enough information for a theory yet. All that exists are some unusual observations. You *must* have a base of data and some understanding and control of the system before you can start creating theories.

Analysis must come before synthesis. Open ended speculation is fun. It's also human nature, but it must be resisted. Jumping to conclusions is probably the greatest error one can make. It immediately makes changing your position difficult. You believe, rather than understand. And, again, once you believe, like the cerealogists or the CEOs, it's hard to be objective.

Be an Explorer

If you were stranded on an island, wouldn't you explore the whole island before deciding where to build your hut? You would gather as much information about the island before making any major decisions. Where is the fresh water? Where are building materials? Are there dangerous areas? And so forth. This is just common sense.

You wouldn't set your camp on the first available spot, would you? You would explore first. You would find the best spot. For all you know, there might be a weather station just over the hill that you could use to radio for help. The same is true when you discover something unusual explore first. Get as much information you can.

And it's important to be systematic and thorough about it. The level of your understanding is directly related to your precision and completeness of your research. Determine how different voltages, frequencies, temperatures, and anything else you can think of, affect the observation.

Again, document your findings. This cannot be emphasized too strongly. Documentation is absolutely vital because it is a critical aspect to replication. If your observations cannot be replicated by others, you will not be taken seriously.

At this point, you are ready to expand your investigation. Now you should visit the library to see if your observations have been reported previously. Note that it is important to do your basic research first. This is for two reasons. The first is that you have to know something about what you are researching in order to compare it to what others have seen. Secondly, I have found that looking at other people's work and explanations tends to limit your own investigations. You do not want any preconceived notions to color your preliminary investigations.

Get an Outside Opinion

If you can't find any corresponding published references that identify your observations, it's time to ask for someone else to look and verify your observations. Typically, this is a coworker or supervisor or someone else who is familiar with the techniques of how the observation is made.

Explain to this person what you have observed. Don't present any theories of what it is. Simply say what you have seen and why you think it is unusual.

The real object of this is to see if you have made some fundamental error. It is very easy to overlook something simple in the excitement of something new. That is why it's important to go slow. (For example, I've seen very strange oscilloscope traces that couldn't be explained, only to have them disappear when a proper ground was employed.)

If that person can't find anything obviously wrong with your apparatus or procedure, and can't explain your observations, it's time to have an independent replication of your findings. Have this person or someone else try to duplicate what you have seen with different equipment in a different location. It would be best if you didn't assist, however, since you know more about it than anyone, your help may be necessary.

If replication is achieved, you can go to the next step. But, if it isn't, it means that you have missed some important factor. This factor must be identified before you can proceed. You may have to place the two versions side-by-side and measure point-by-point to see what is different between the two.

However, once you solve this problem, you will understand the observations better.

Report Your Observations

Now is the time to publicly document what you have seen. This paper should report what you have seen, why it is unusual, and why it is important.

Do not, as yet, try to interpret the results in the paper. This paper should be circulated to those most able to understand what you are saying. Be complete. Provide raw data, as well as any analysis that you have done.

Try to anticipate the reader's questions and address them. Do not be afraid to raise questions that cannot be answered. (For example: The effect appears to be the transmission of an electric charge without the transmission of an electric current. How can this be?)

You may be concerned about intellectual property. This is your idea. You may want to protect it. This is a real problem. In order to protect your idea, you have to be secretive. But, to be taken seriously, that is be

REFERENCES

www.skepdic.com
(sic) for N-rays and crop circles

www.news.bbc.co.uk/2/hi/eng land/2310127.stm
for crop circles

credible, you must provide ample details. This will not be discussed further because this article is about fooling yourself, not intellectual property protection.

But secrecy tends to enhance fooling yourself because it doesn't allow others to comment or duplicate your observations.

Develop a Theory

Only now should you think seriously about explaining what you have seen. You should be able to replicate your findings at will. You should be able to modify the apparatus and predict what will happen.

In short, you should already understand what you are seeing. The "theory" evolves from experience rather than imagination. In fact, the theory is just a refinement of the basic concepts that you have gathered so far. A good theory is something you learn rather than something you create.

Of course, there may be alternative explanations for your observations. Here, Occam's razor is useful. That says that the simplest answer is usually the best answer. Are crop circles the result of aliens or resourceful humans? Occam's razor chooses humans. When astronomers first detected pulsars, they were perplexed and excited. They found repeating pulses with intervals that were accurate to many decimal places very much like radio beacons. There was no theory, at that time, to explain what they were seeing. There was some informal suggestions that these were the evidence for LGM (little green men) or extraterrestrial intelligence. However, further study into celestial mechanics revealed that rotating neutron stars could generate pulsed signals with high precision. So the LGM idea died, quietly and quickly, because of Occam's razor.

Non-repeatability

What should you do if something is not-repeatable? Sometimes this happens. Sometimes an effect only appears on occasion. It may certainly be the case where some subtle environmental variation has a significant effect on your observations. This is the case of extracting a signal from noise. Here, it is critical not to speculate or theorize.

Again, understand rather than believe. Make your measurements as precise as possible. Use statistics to show cause and effect. And be sure to use the proper statistics in the proper way. Using poor statistics is a very good method of fooling yourself. (For example — many ESP studies are statistically flawed.) If you have to use statistics, you should emphasize description rather than explanation in your ideas.

Human Nature

As we've seen, the real problem with fooling yourself is human nature. It's natural to try to explain something that doesn't make sense. This is the primary cause of superstitions. And, it is clear that humans are a superstitious lot. (Note, animals can be trained into superstitious behavior, too.) Silly ideas can be considered a type of superstition.

It's fun to watch a movie about ESP or aliens or magical powers. It's fun to imagine strange and unusual explanations for some odd observations.

But, it's important to separate fun from serious study. If you want credibility, take care in your measurements and reports. Be conservative. Be complete. Be precise. Be foolproof. Would you rather be associated with cold fusion and N-rays or with gene splicing and lasers? **NV**

Tech Forum

QUESTIONS

I would like to locate a Honeywell Timetracker or something similar. I have contacted Honeywell and have received no response. I know there is a *large* commercial one available, but it would be unsuitable.

If I have to build one I would need a schematic. If this is the case, I would like **1)** an adjustable off/on adjustment at daylight; **2)** an on and off output, and a DPDT relay. One pole dry to use with X10 and the other for 120V AC at 500- or 600-watt range.

#7031 **K.V. Gentry**
Springfield, MO

I found two hybrid IC power amp modules in my electronics stash, and beyond what they are, I cannot identify them further.

One is marked "Sanyo power amplifier SS1001." The code on the back is 86AE303. The other is marked "The Fisher pa501 Hybrid IC power amplifier module." The code on the back is 50HL093.

They are in rectangular cases, a screw hole for mounting is on each end, and 10 solder terminals (for PC mount) are along one side. The case size is 3" long, 1.75" wide, and 1/4" thick.

Does anyone have a cross reference, hook-up diagrams, or specifications? Google was no help.

#7032 **Mike Arman**
Ormond Beach, FL

I need information about Uninterrupted Power Supply maker, "Electro Vector."

My Electro Vector SRP-500A back-up power system recently conked out. Before I junk it, perhaps there is a successor company or some firm which can supply replacement components?

It has been about six years since I communicated with the company. There is no answer at the last phone number I had for them and my letter to Electro Vector in Forrestville, CA, was returned.

#7033 **Jack Meagher**
Southern Shores, NC

Is there such a cable with an upstream (square) USB plug at one end, and a 37-pin female (parallel) plug at the other end? If so, can someone recommend sources?

I'd like to connect my USB 2.0 printer to a parallel switch box since *all* my USB connections have already been taken and, so far I haven't seen a USB switch box!

#7034 **Dave**
via Internet

I need to synchronize an audio file on my computer with my VCR (and/or DVD player). I'd prefer an actual timing signal, but could have the sound play when the play button on the remote is pushed.

#7035 **Seth Reeder**
via Internet

I need an economical way to measure the fuel consumption in my 1981 DeLorean. It has a Bosch CIS, mechanical fuel injection system and the fuel flows to the fuel distributor and back to the fuel tank.

One possibility is using two fuel flow sensors. One in the feed and one in the return and then subtracting the two numbers. I cannot find inexpensive fuel flow sensors.

I believe I can approximate the fuel flow by measuring the position of the "air metering plate." (This is a metal disc that sits in the air column and gets deflected downward as the air flow increases.) Since the air/fuel mixture is held pretty constant, I believe the position of this plate would give valuable info. How can I measure

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

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ANSWER INFO

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

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To be considered

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

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

Information/Restrictions

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

Helpful Hints

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

the relative position of this plate or fuel or air flow?

#7036 **Dave**
nandv@d2tech.net

I'm building a handheld detector to receive low-pulse energy waves from spurious non-modulated RF transmission sources. These transmitters are a health hazard to human and animal life. The detector only needs to be a deflection meter, etc. How or where do I attain such a device?

#7037 **Paul Recupero**
Portsmouth, RI

I have for some time been trying to design an electronic circuit that I would like to work in the GigaHertz frequency range, but I cannot find any information on what electronic components I could use or where to find such information.

#7038 **Charles Kenwood**
Lincoln, NE

I teach electronics to electricians and a question came up about how the cable companies can get the different stations and numbers correct that are assigned to the correct channels?

I have tried many areas and no correct answer yet.

#7039 **Gus Scacco**
New Hyde Park, NY

I need a system that will let me combine two composite video signals into a single 'picture-in-picture' signal with one image superimposed over the other. Until recently, you could buy stand-alone units, but it seems that they are only available as built-in options now.

Are there components that can be used to build a small PIP?

#70310 **Jeff Pelz**
Rochester, NY

I own two computer programs that use the old flat format FCC databases formally available on the FCC web site Media sub page. The FCC discontinued providing these databases once they switched to their new CDBS database. Does anyone have a conversion utility or program that can convert the FCC's CDBS database to the old flat format FCC databases?

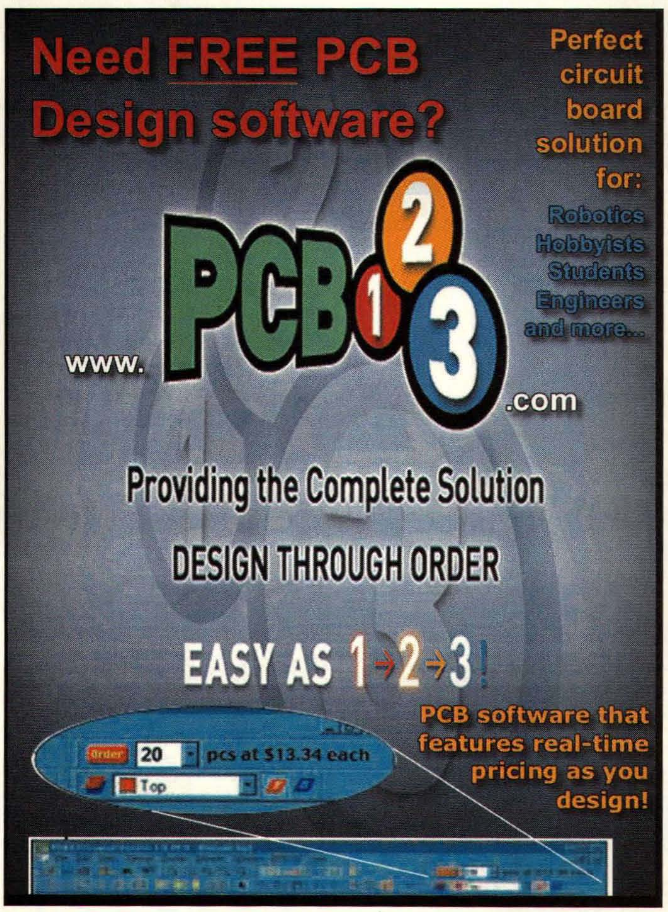
#70311 **Edward J. Wilk**
Oak Park, IL

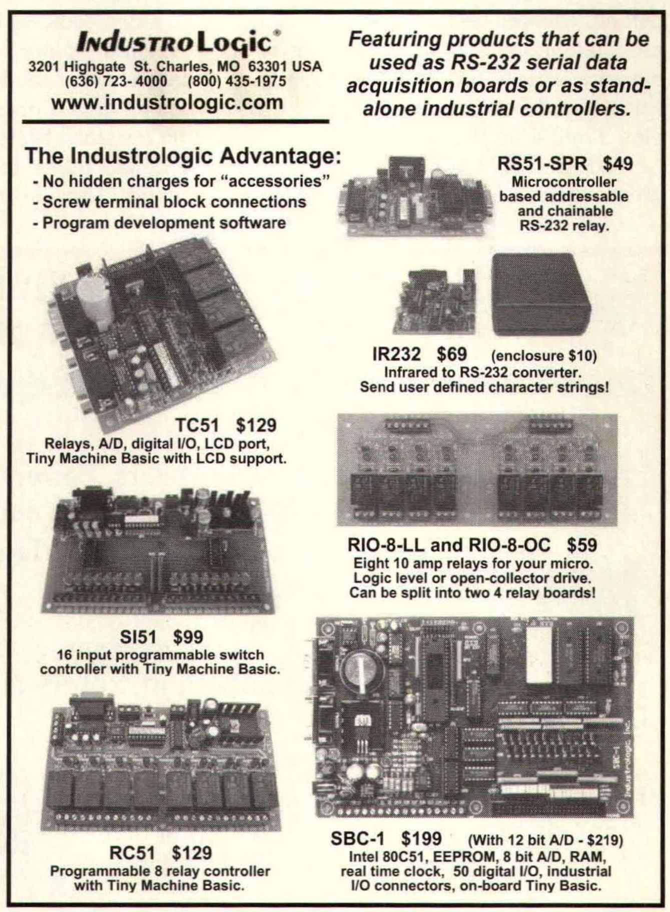
ANSWERS

[20311 - FEB. 2003]

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

http://download.com.com/3120-20-0.html?qt=.cad+viewer&tg=dl-2001 is the Cnet download page with numerous CAD viewers. They are typically free to try, then you pay something to keep it. Some are crippled until purchase, some are all there until it reaches some timeout,





and some are there for free.

www.pentalogix.com/ is yet another free PCB viewer, for Gerber files. Be careful, they have their for-pay pro-versions here, too.

KenJ
via Internet

[4035 - APR. 2003]

I need a diagram/schematic for a test device that I could plug into any RJ45 jack in a room and get a light or tone if that port is active ... connected to a hub or switch. Yet, not if I plug into a phone system.

I'm tired of running around at a customer's location with my laptop, looking for an active port.

There are several commercially-available RJ45 testers, many under $100.00. These will test cables and also check for activity. However, if you want an understanding of the actual set-up of the connector, you can build your own with a bit of fiddling.

An RJ45 connector has eight pins. The "standard" set-up is for pins 1, 2, 3, and 6 to be used for ethernet. It seems that the center two pins (4 and 5) are by default reserved for the telephone, since on a telephone system the center two pins are usually the first telephone line (pins 2 and 3 on the four-pin RJ11, or pins 3 and 4 on the six-pin RJ12).

These are usually the red and green wires on a telephone line, with the yellow/black wires going to the next pair of pins outward for a second phone line.

The use of the center two pins for analog voice is carried over to RJ45 connectors.

Now there are many, many exceptions to this basic principle. You may be in a building that is using a digital telephone system. It may or may not be using the center two pins for analog voice. Full duplex, high-speed ethernet configurations use more than the four pins above. So, beware. However, there are some simple tests you can incorporate into your tester that will sort out many of the default setups. For instance, if indeed the center two pins are analog telephone, then the voltage with no handset (no load) connected will almost certainly be over 20 volts, and more likely nearly 50 volts (DC). You should also be able to take a low-current LED and use a 1K resistor (experiment, probably 100 ohms to 5K, depending on the LED) in series to test for activity on the ethernet pairs (pins 1-2 and pins 3-6).

If you use two LEDs and resistors, you can look at both the receive and transmit pairs simultaneously. Be careful about loading down the line, and use as high a resistance as possible for the resistors. Better yet, would be to use a CMOS buffer to drive the LED, but I cannot provide more detail on that here. Unfortunately, I have seen activity on a jack using a commercial tester and occasionally still not had success on connecting.

A final thought would be to buy a $30.00 hub, perhaps convert it to batteries and use that as your tester. Most hubs now have LEDs for activity on all the ports and it is much quicker to plug it in that plug in and configure your laptop. The bonus is that the buffering is built in and you do not have to worry about loading the line.

Joe Heck
Wrentham, MA

[4034 - APR. 2003]

In an exclusive OR gate, can there exist more than two inputs? If so, how would you explain the output?

#1 Yes, an XOR gate can have more than two inputs. To simplify the explanation, think of these gates as parity generators. The output will be high if an odd number of inputs are high. It will be low if an even number (including zero) inputs are high. Checkout the data sheet for the 74AS286 at **www.ti.com** for a nine-input XOR parity generator.

Mike Blazer
San Antonio, TX

#2 Yes, there can be more than two inputs. In fact Fairchild Semiconductor builds one under part number NC7SZ386. Its truth table is that of a half adder with carry-in function. Here's the truth table for a three-input and four-input exclusive or gate:

3-Inputs	Output
ABC	Y
000	0
001	1
010	1
011	0
100	1
101	0
110	0
111	1

4-Inputs	Output
ABCD	Y
0000	0
0001	1
0010	1
0011	0
0100	1
1010	0
0110	0
0111	1
1000	1
1001	0
1010	0
1011	1
1100	0
1101	1
1110	1
1111	0

A search of the web for "3 input exclusive or" will return many hits with various information. A search for "4 input exclusive or" will get you many hits with various information including how to create one using a Xilinx gate array.

Larry Nolen
Bealeton, VA

#3 There can be more than two inputs to an XOR gate, however, I've never seen anything but two-input gates available in standard TTL or CMOS logic. XOR gates are normally expanded to provide more inputs just like an AND or OR gate is expanded, but doing this goofs up the exclusivity of the XOR truth table. By definition, when one, and only one, input of an XOR goes to a logical HIGH, the output goes to a logical HIGH; all other input conditions result in a logical LOW output. This implies that a true eight-input XOR gate will have only eight out of a possible 256 input conditions where the output goes to a logical HIGH. The most common expansion of an XOR gate is to expand it like an AND gate and any number of expansions such as that have a rather different definition: if an odd number of inputs go to a logical HIGH, the output will go to a logical HIGH; all other input conditions result in a logical LOW at the output. Either logical description of a two-input XOR will yield the same truth table. But an eight-input expansion of this type results in a lot of possible conditions where the output goes HIGH. Such a circuit can be used as a parity generator or parity checker, and as such, ends up being the most common expansion of the XOR, although it doesn't fit the "proper" XOR truth table, and is usually buried in a much larger integrated circuit function so that you'll never know it's there.

Dean Huster
Harviell, MO

[5031 - MAY 2003]

I am looking for a kit or circuit for building a date/time generator for a CCTV camera/VCR set-up. I use a composite signal only.

I use my CCTV cam for recording lunar and planetary AVIs. I'm also seeking information or circuit on video integration.

#1 There is a circuit that generates ASCII text through NTSC. This circuit is known as an ASCII text generator. This device requires an input device such as a keyboard to control the displayed text. Although one could make a microcontroller such as a BASIC Stamp input the text.

Several electronics suppliers carry this device. One supplier I remember carrying this device is MCM Electronics The device looks like a single in-line memory module. Their web address is **MCMElectronics.com.**

Leonard Sexton
Ft. Stockton, TX

#2 Since you sent in your request via the Internet, it's very likely that you have a computer. You may want to check out AstroVideo which is a free download at: **www.ip.pt/coaa/astrovideo.htm.**

I am using this program with a cheap USB video digitizer into a laptop computer and the results are absolutely amazing. I can image objects that are extremely difficult to see especially with the level of light pollution that I must put up with. I've found that by stacking hundreds and even thousands of video frames it's possible to see objects that are otherwise not visible to the naked eye! Keep in mind that when using NTSC video you can record at approximately 30 frames per second!

The program offers video integration and drift tracking (which is helpful if you are not able to precisely track an object) along with a multitude of other very neat features. AstroVideo also has the ability to time stamp individual frames. So if timing is important, all you have to do is make sure the computer clock is set accurately.

You may also want to check out AstroStack at: **www.astrostack.com** which is also a free download.

If you have further questions or would like to see some astrophotos taken using AstroVideo and AstroStack check out: **www.k3pgp.org.**

John
via Internet

[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? What is the phone jack in the back for? Is it for RS232 communications and, if so, what is the criteria for communication? There is a slot in the back, is this for programming the converter? What is the pinout on these jacks or *connectors?*

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

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

[5035 - MAY 2003]

I have an old Dish TV satellite receiver that is a single LNB. Is there anything it can be used for? Maybe picking up weather or some kind of free data? (I don't mean illegal hacking.) Or maybe connect a BASIC Stamp to it?

#1 A number of people have started using spare dishes of various sizes for Amateur Radio Astronomy. Although the larger C/K-band dishes are more appropriate, many people have had success using the smaller dishes at short wavelengths as radio-telescopes.

By connecting the dish to a total power or tuning meter, one can actually use the dish to detect relative intensity of radiation. The sun typically will peg the needle, and the moon will give fairly strong readings, as well. Warm surfaces and people will cause deflection of the needle, as well. Typically, it is this "total power" output which one wants to measure for amateur radio astronomy. An example of a dish used this way can be found at: **www.radiosky .com/12ghz.html.** This site also has information on building interfaces and software to use with various telescope designs.

If you replace the power meter with a DAQ or even connect it to a PC sound card, it is possible to graph or process the data. The rotation of the earth will swing the telescope's beam through a known path, and allow you to measure background "cosmic noise," especially significant sources such as the galactic plane.

Gary Coulbourne
Lansdale, PA

#2 There are many uses that you can use an old surplus dish for. I've seen them used to receive weather satellite data from orbiting NOAA satellites to construct weather maps like those you see on the news. But this requires an LNA and receiver different than the ones you have. I have seen them used to make long distance wireless local area network links, but again, requires a different set of electronic hardware.

One of the more useful set-ups I've seen a dish used for is to heat water. You can have the semi-parabolic dish chrome-plated to a high shine and polished. Then take a length of copper tubing and coil it to be placed in a tin can so that water can be ran through the tubing. Paint the tubing and the inside of the can flat black and mount it on the LNA boom so that the sun's reflection is concentrated on the tubing and can. When water is ran through the tubing it will be heated by the sunlight.

There are also several microwave bands that scanner enthusiasts listen to. The dish could be used to downconvert those high frequencies into frequencies that a receiver can use. The dish is highly directional so one could point it at an area of interest until a channel is found with activity. An organization called SETI has an experimental distributed radio telescope array based on consumer satellite technology. I believe that they are looking for volunteers to set up their surplus equipment to monitor frequencies that may show signs of intelligent life outside of our own solar system.

I hope that these ideas spur your imagination into creating something out of a piece of hardware that could otherwise go to waste.

Larry Wheeler
Ft. Stockton, TX

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