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November 2003

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TABLE OF CONTENTS

Vol. 24 No. 11

PROJECTS

FEATURED ARTICLES

ON THE COVER
"Sea Of Hi-hats"
by Dennis San Vicente

COLUMNS

DEPARTMENTS

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Dear Nuts & Volts:

This is a humble request for the editorial staff of *Nuts & Volts* to press their contributors to publish source code to microprocessor driven articles. An otherwise excellent article, written by respected authors, is reduced to "advertising fluff" for a commercial product when the source code to their article is kept secret. Such articles are incomplete leaving some readers wondering about the rest of the story.

Let us agree to leave the *infomercial* in the hands of broadcast television where it may represent an improvement in programming.

Edward W. White
via Internet

Dear Nuts & Volts:

I thought I would just send you a note thanking you for the excellent "Let's Get Technical" column by James Antonakos in the Sept. 2003 issue. I just substituted V_T "Vtotal" for your "E. " I push and push my students to learn the basics. Your article struck home. They come to me looking to work with high tech stuff first before having an inkling on the basics! I teach grade 9 to grade 13 here in London, Ontario. I incorporate many topics altogether in one project to attempt to accomplish the same effect and make it interesting. We recycle a lot of old circuit boards that get donated to the school (transistors just don't go bad), so as a project worth 10 marks, I have the students desolder five different resistors that add up to as close as they can to 1,000 ohms. They solder them together (in series) starting from the lowest value to the highest. Then they must calculate the voltage drop that will occur at the four joints. Then they attach a power supply that they must set to exactly 10 volts in advance with no load.

The voltage divider is powered up (1,000 ohms makes it 10 mA of current flow ... a nice low number, less smoke number for me) and measured with a DVM to check their calculations. It sounds like a lot of work, but they soon learn how to take a component out without damaging the circuit board. They learn how to solder components together, they learn the color code quickly, they learn Ohm's law, Kirchoff's series circuit laws, how to use a DVM, and how to use a power supply. And it enforces the idea of measuring across each resistor to get voltage drops — all at little or no expense to the school — and you can do it a zillion times and no two are the same, so they can't copy (ha ha). Great article ... more, more, more!!!

Richard Blow
Saunders Secondary School
London Ontario, Canada

Dear Nuts & Volts:

In regards to the Levitation article in the Sept. 2003 issue ... a tip: If you don't want to smash the Hall Effect sensor with the electromagnet, cut a slot in the bolt head just deep enough to allow the magnet to hit the head of it without being able to smash the sensor. The sensor used should activate entirely through one of its flat sides so that the riser metal on either side of it won't affect its sensitivity.

Hilary Ryan
Sorrento, FL

Dear Nuts & Volts:

You've probaby had many others point out the irony of there being a typo on page 95 of the September 2003 issue right underneath the "Check those facts" box, where a new scientific unit has been introduced, the Kelvin-Hertz (KHz).

To complete the irony, two paragraphs later is the title "Accuracy, Completeness, and Clarity" wherein it is discussed what happens when you say something wrong in a publication. I'll bet Gerard meant kHz but hey! I can't let an article on writing get away with such a miscommunication ...<grin> Now let's see, what have I misspelled ...

Jonny
San Diego

This was my fault, due to the ambiguity of using kHz in RF vs. KHz in digital computing. IEEE suggests kHz, though I presume the readers of Nuts & Volts are smart enough to infer context, and not confuse MHz with Molar-Hertz.

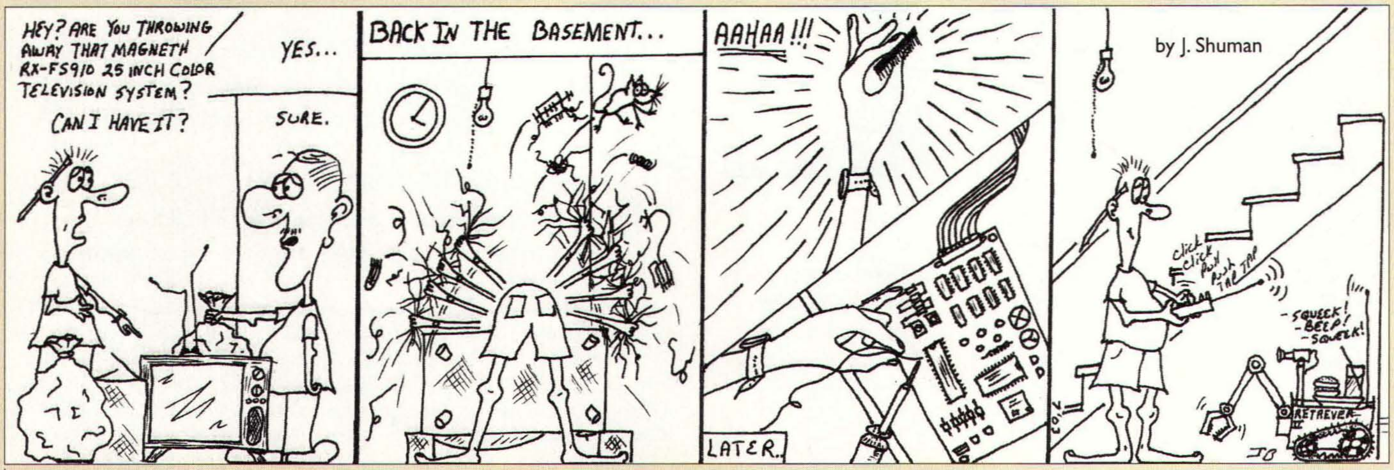
– Editor Dan

Dear Nuts & Volts:

I was a *Poptronics* subscriber that was introduced to *Nuts & Volts* when *Poptronics* was discontinued. I've been very pleased with *Nuts & Volts* issues that I have received since the demise of *Poptronics*.

However, I would like to point out that the Apple G5 is NOT the first 64 bit processor for personal computers. A 64 bit processor has existed for well over a decade – the Digital Equipment Corp. Alpha. The first Alpha was the DECchip 21064 introduced in February of 1992. I have been using DEC Alpha based 64 bit processors for nearly its entire lifespan. I am typing this message on a dual

Continued on Page 74



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FOUNDER/ASSOCIATE PUBLISHER
Jack Lemieux

PUBLISHER
Larry Lemieux
publisher@nutsvolts.com

ASSOCIATE PUBLISHER/ VP OF ADVERTISING SALES
Robin Lemieux
display@nutsvolts.com

MANAGING/TECHNICAL EDITOR
Dan Danknick
dan@nutsvolts.com

CONTRIBUTING EDITORS
Jon Williams
Jeff Eckert
TJ Byers
James Antonakos
Thomas Scarborough
Thomas Henry
Michael Banks
Ed Driscoll
Ray Marston
Stanley York
Mike Keesling
Gerard Fonte
Paul Florian
Mark Balch

CIRCULATION DIRECTOR
Mary Gamar
subscribe@nutsvolts.com

SHOW COORDINATOR
Audrey Lemieux

WEB CONTENT/NV STORE
Michael Kaudze
michael@nutsvolts.com

PRODUCTION/GRAPHICS
Rosa Gutierrez
Shannon Lemieux

DATA ENTRY
Karla Thompson
Dixie Moshy

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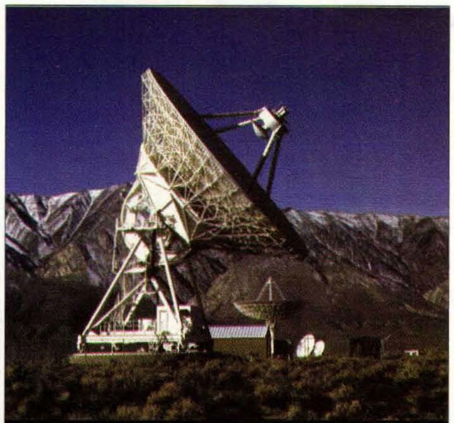
Events, Advances, and News From the Electronics World

Advanced Technologies


The Owens Valley, CA, antenna is one of 10 in the VLBA system. Each weighs 240 tons, is 25 m in diameter, and stands nearly as tall as a 10 story building. Image courtesy of National Radio Astronomy Observatory/Associated Universities, Inc.

VLBA Reaches Age Ten

In case you missed it, 2003 marked the 10th anniversary of the National Science Foundation's (**www.nsf.gov**) Very Long Baseline Array (VLBA), a continent-wide radio telescope that is used primarily to view information that happened an inconceivable number of years in the past, at an incomprehensible distance, revealing things that most of us don't understand. Dedicated in 1993, the $85 million system includes 10 240-ton antennas located from Hawaii in the west, to the US Virgin Islands to the east. They are controlled by the Array Operations Center in Socorro, NM, and function as a single instrument.

Acting like a 5,000-mile-wide eye, the VLBA can produce the sharpest images of any existing telescope, whether Earth or space based. It is said to deliver resolving power equivalent to standing in New York City, and reading a newspaper in Los Angeles. Major achievements of the VLBA include the most accurate distance measurement ever made of an object beyond the Milky Way, the first mapping of the magnetic field of a star other than the Sun, "movies" of cosmic jets and supernova explosions, the first measurement of the propagation speed of gravity, and other notable observations.

Computers and Networking

Laptop Features 3-D Display

Billed as the world's first notebook computer incorporating a 3-D LCD monitor, the PC-RD3D machine from Sharp Corp. (sharp-world.com) is slated for availability with a Japanese-language OS and keyboard before the end of 2003, with the English version to come later. Users can switch between standard 2-D and 3-D viewing, and no special glasses are required for either. Using a "parallax barrier system," the LCD incorporates a "liquid switching crystal" that controls light as it leaves the display, such that the viewer's right and left eyes see different images. When the liquid switching crystal is disabled, light is emitted in the standard way.

The computer itself is based on a 2.8 GHz Intel® Pentium® 4 microprocessor and a NVIDIA® GeForce™ 4 440 Go graphics chip. It features a 15-inch display, a built-in DVD drive, and a 60 GB drive. Word on the street is that it will be priced at just under $3,000.00.

Confuse Address-Harvesting Robots

As you probably know, among the tools used by spammers to invade your Email system are "robots" that crawl the web and harvest addresses from web sites. If your address is placed somewhere in public HTML code, it is likely to be distributed to millions of spammers worldwide within 12 seconds or so, after which you will be bombarded with dozens of daily offers of cheap mortgages, Russian brides, herbal Viagra, huge sums of cash from Prince Kwame Kuffor of Ghana, and, of course, penis enlargement pills. (I have yet to encounter an offer for penis reduction pills, which shows how little Email marketers know about their intended customers.) But the folks at Hiveware (**www.hiveware.com**) have developed a way to avoid that (at least until the spammers figure out how to get around it).

All you need to protect Email addresses in your web site is Hiveware's Enkoder application. According to the company, "The Enkoder will encrypt your Email address and wrap the result in JavaScript, hiding it from Email-harvesting robots — just paste the resulting JavaScript into your web site HTML. Your address will be displayed correctly by web browsers but will be virtually indecipherable to Email harvesting robots.

Instead of merely breaking up and printing out a standard **mailto:** tag, the Enkoder generates a unique and random key and ties that to an encrypted array containing your address for even better protection. Furthermore, the Enkoder uses a genetic algorithm to generate the JavaScript so it's different every time. Because the JavaScript changes each time you run the Enkoder, it is virtually impossible for spammers to parse and decode your address."

Best of all, Enkoder is free. Enkoder 2.0.5 runs only on Mac OS X 10.2 (Jaguar), but Hiveware also offers the Enkode Tool command-line version, which is available for Windows, Linux, FreeBSD, and the Mac OS.

Industry and the Profession

Library of Congress to Offer 80,000+ Movies

It has been announced that three universities (the University of Washington, Rutgers University Libraries, and the Georgia Institute of Technology Interactive Media Technology Center) have received a $900,000.00 grant to build the Library of Congress' (**www.loc.gov**) first centralized online catalog of film, television, and digital video images from libraries, national archives, museums, and broadcasting companies. Known as the Moving Images Collection (MIC), the centralized online catalog ultimately will be the largest repository in the world for digital moving images. It will expand the Library of Congress' ability to provide video images of the nation's most treasured and important images, including archives in the national Smithsonian to video from the Hubble telescope, all as one resource that is accessible over the Internet. When completed, the MIC will work much like an Internet search engine except that it will be modified to locate moving images only.

The MIC databases and web portal will be powered by two IBM eServer p630 and two IBM eServer p610 models running SuSE Linux Enterprise SLES 8 and leveraging the IBM directory server. The eServer p630 and p610 systems will serve as the gate to the database and permit users to search and locate the moving images. After finding the video images with MIC, users can then make arrangements directly with the content providers to obtain permission to view or reference the moving images. Many moving images will be available for direct streaming via a link in the catalog record.

Apple Enters Supercomputing Realm

As perhaps an early indication that Apple Computer's (**www.apple.com**) G5 machines are getting some market traction, it was recently announced that Virginia Polytechnic Institute (better known as Virginia Tech) is building a supercomputer cluster that will use 1,100 of the G5 64 bit, 2 GHz, dual-processor computers. Clustering technology is a popular choice among educational institutions that want to deploy supercomputing power without spending a great deal of money on a large machine. The G5 is said to offer excellent floating point performance, a key requirement of many scientific computing applications.

"Virginia Tech's idea was to develop a supercomputer of national prominence based upon a homegrown cluster," Hassan Aref, dean of Virginia Tech's College of Engineering, said in a statement. The new cluster is designed to make its way into the rankings of the world's largest supercomputers, a list that currently includes no Macintosh machines. Virginia Tech will use the cluster to perform research on nanoscale electronics, chemistry, aerodynamics, molecular statics, computational acoustics, and molecular modeling, among other tasks.

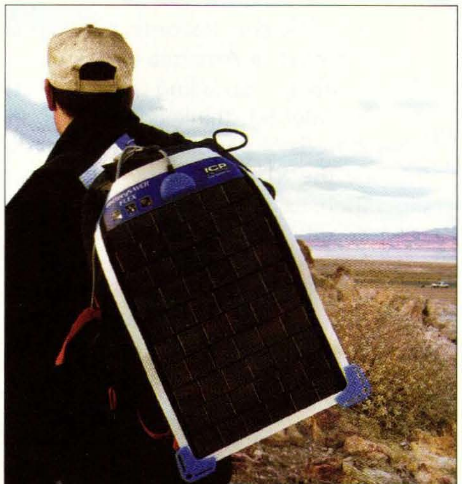
The servers in the cluster will be connected through 24 high-speed Infiniband switches from Mellanox Technologies (**www.mellanox.com**). Infiniband, which was developed by a consortium of server and storage companies, was designed to provide greater bandwidth than other interconnect technologies.

RIAA Shows Its Fangs

If you think the Recording Industry Association of America (RIAA) isn't serious about curtailing music theft over the Internet, think again. Among the hundreds of people who have been sued by the RIAA for using download sites such as Grokster and Kazaa, is 12-year-old Brianna LaHara. The organization extracted a settlement of $2,000.00 from Brianna's single mother as compensation for the girl's downloading of children's songs such as "If You're Happy and You Know It, Clap Your Hands." In a way, the sum is a bargain, given that US copyright law allows penalties of up to $150,000.00 per song.

Fortunately, P2P United, an association of six file-sharing web sites, has offered to pay the fine. According to the group's executive director, Adam Eisgrau, "We don't condone copyright infringement, but it's time for the RIAA's winged monkeys to fly back to the castle and leave the munchkins alone." But don't expect the P2P United to come to your rescue — this is a one-time gesture that will not be repeated. (As of this writing, the **www.p2punited.org** site is under construction, but there may be something there by the time you read this.)

Circuits and Devices



ICP Global offers a line of flexible solar panels that can be mounted nearly anywhere. Photo courtesy of ICP Global Technologies.

Portable Solar Power Up to 20 W

A relatively new development from Canada's ICP Global Technologies (**www.icpglobal.com**) is Battery SAVER FLEX™, a portable solar panel that can be used not only for charging batteries but also as a direct power source for GPS units, cell phones, laptop computers, and other portable devices (using the optional 12 V power socket).

The unit incorporates technologies developed by NASA and the military, using non-breakable copper-indium-gallium diselenide cells that are stable and long lived, even in the extreme ambient conditions of space. The malleable construction and mounting options make it suitable for installation on boats, RVs, campers, and even (as shown) on backpacks for use while hiking.

When not in use the panel can be rolled up and stored in a bottle or tube. BatterySAVER FLEX panels are available in 5, 10, and 20 W configurations.

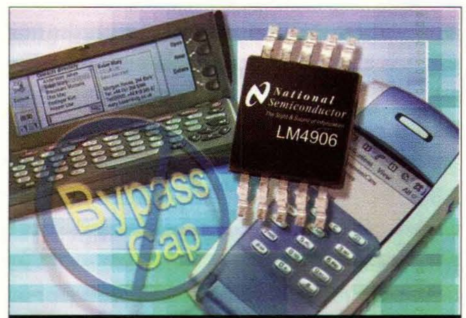
Available from online stores such as Boat US (**www.boatus-store.om**) and West Marine (**www.westmarine.com**), they will set you back by about $150.00, $250.00, and $480.00, respectively, including a three-year warranty.

Audio Amp Eliminates Bypass Capacitor

National Semiconductor (**www.national.com**) has introduced the LM4906 Boomer® audio amplifier, which eliminates the bypass capacitor typically connected to the reference voltage pin. According to the company, the new architecture improves power supply rejection ratio (PSRR) and provides fast turn-on times, making the device suitable for applications in small, portable devices such as mobile phones and notebook computers.

Designed to improve overall system performance, the LM4906 is capable of delivering 1 W of continuous average power to an 8-ohm bridge-tied load (BTL) with less than 1% total harmonic distortion plus noise (THD+N) from a 5V DC power supply. The LM4906 has an internal selectable gain of either 6 or 12 dB. It does not require output coupling capacitors or bootstrap capacitors.

The LM4906 contains advanced pop-and-click circuitry that eliminates noise during turn-on and turn-off transitions. Additionally, the LM4906 features a low power consumption shutdown mode (the part is enabled by pulling the shutdown pin high) and an internal thermal shutdown protection mechanism. The LM4906 is available now in chip-scale and miniature SOIC packaging and is priced at $0.60 in 1,000-unit quantities. **NV**



National's LM4906 audio amplifier eliminates the bypass capacitor, saving board space. Courtesy of National Semiconductor Corp.

Electronic Theories and Applications From A to Z

Let's Get Technical

There's More Simple Stuff?

Do You Know Your 1, 10, 11s?

In the last column, we examined the importance of knowing the basics of DC and AC circuit analysis. This month the spotlight is again on the basics, but now I shift the focus to digital electronics. Right off the bat it's important to understand that digital electronics is not just wiring logic gates together or drawing schematics. It's also about mathematics and pattern recognition.

Well, that sounds like enough of an excuse to avoid learning some of the finer points of digital design! But it's a fact that to ignore the simple mathematics of Boolean algebra when working with digital circuitry leads to trouble. Consider the digital circuit shown in Figure 1. There are two inputs, A and B, and a single output F. What does the truth table of the circuit look like? One way to determine the answer is to apply all four AB input combinations (00, 01, 10, and 11) and figure out what F equals for each pattern.

Another way to analyze the circuit is to see that the output F will be high if either AND gate outputs a logic one. So, what do we need to get the AND gates to output this high logic level? The upper AND gate requires that A and B are both high, while the lower AND gate needs A to be high and B to be low. Figure 2 shows the resulting truth table.

Figure 2. Truth table for the logic circuit of Figure 1.

A	B	F
0	0	0
0	1	0
1	0	1
1	1	1

Now, as the truth table clearly shows, the output F is high whenever input A is high — no matter what input B is doing. Input B has no affect on the output! In fact, we don't even need the four logic gates, since F equals A for all four input combinations. The circuit reduces to just a wire from the A input to the F output. Here we use the pattern we see in the truth table to help us reduce the circuit.

It's a doomed company that will manufacture circuits like the one shown in Figure 1, as they are wasting their money on logic they do not need. This applies to digital circuits built the old-fashioned way with individual TTL ICs, as well as to newer circuits designed for operation within PALs, GALs, CPLDs, or FPGAs.

How does one recognize a circuit that contains useless gates? That is a difficult thing to do. However, there is still another way to analyze a digital circuit that is straightforward and leads to a simplified version with a minimum of fuss. Here is where the math comes in.

Figure 3 shows the original cir-

Figure 4. Truth table for the OR gate.

A	B	F
0	0	0
0	1	1
1	0	1
1	1	1

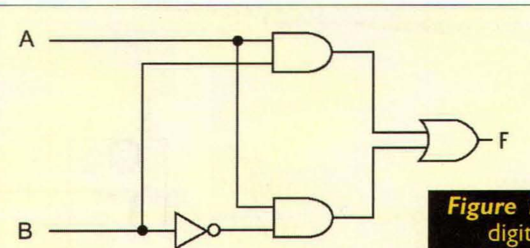


Figure 1. Simple digital circuit with two inputs and one output.

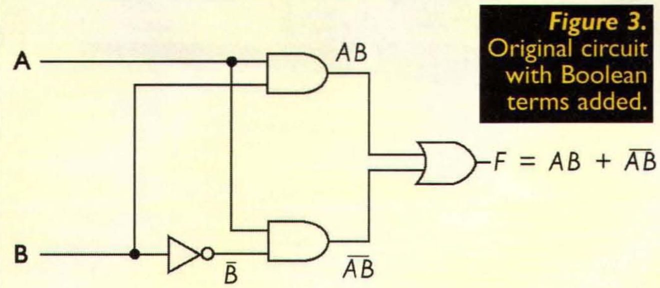


Figure 3. Original circuit with Boolean terms added.

cuit with the addition of the Boolean terms for each logic element. Now, look closely at the equation for the output F. Since input A is common to both terms in the equation, we can factor the equation and get

$$F = A(B + \overline{B})$$

What we now have is an equation that translates into a circuit with one less logic gate (we eliminated an AND gate by factoring). Although this is not always the case, we often get a reduction of one gate by factoring. The trick now is to recall that the term

$$(B + \overline{B})$$

always reduces to a one, which allows the equation to simplify to F = A. So, knowing a simple Boolean identity and a little mathematical factoring, we have reduced the original equation down to its simplest form. Clearly, it pays to examine a Boolean equation to see if there are reductions possible.

Remembering that

$$(B + \overline{B})$$

is always one allows us to perform the Boolean reduction. But why is this term always equal to one? The truth table in Figure 4 shows why. With the B input and its inverted value both input to the OR gate at the same time, we always have a 01 or 10 combination present on the inputs, so the output is always high.

When the Boolean equations have a small number of terms it's possible to compare the individual terms together, looking for pairs that factor and reduce. Unfortunately, you can over-compare and actually start adding unnecessary terms back into the equation. The more advanced methods of Karnaugh maps and Quine-McCluskey eliminate this problem.

But even someone skilled at reducing Boolean equations must look for other ways to implement the circuit when necessary. For example, a logic board already crammed with ICs may not be able to support the addition of a new IC — there is no room available. But what if the customer requires a modification to the circuit and a NAND gate is

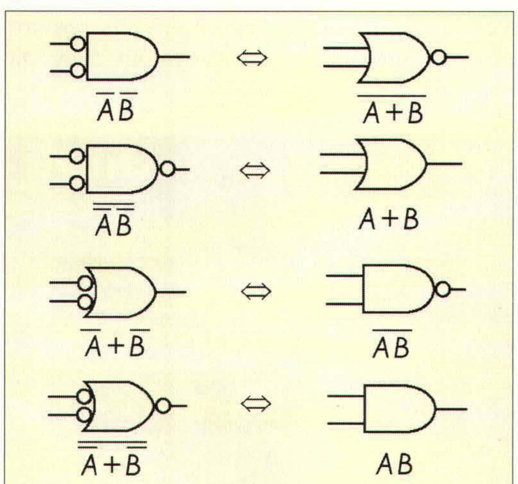
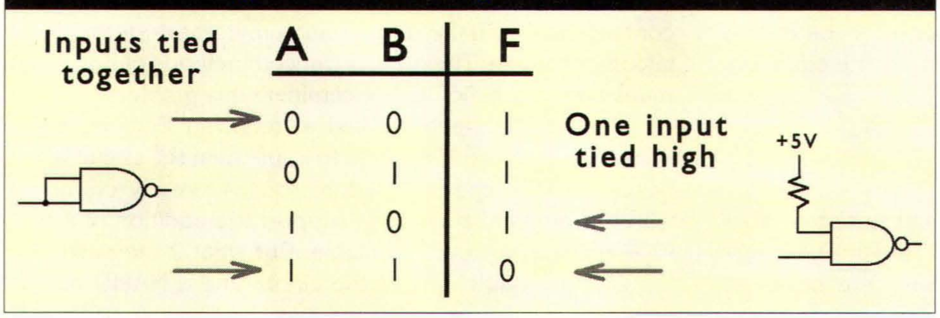


Figure 5. Logic function equivalent relationships.

Figure 6. Inversion using the NAND function.



required to complete the modification. If there are no spare NAND gates on the board, and we can't add another IC, are we lost? Before we give up, we look around at all the spare gates available on the board. If there are two spare inverters and a spare OR gate available, we can synthesize the NAND function. Figure 5 shows the equivalent relationships between the various two input logic gates. These relationships are covered by DeMorgan's Theorem, which requires the inputs of one logic function to be inverted to mimic the behavior of a different logic function.

Additionally, it pays to remember other gate substitutions that allow us to mimic the operation of the inverter. For example, a NAND gate may act like an inverter by (a) tying its inputs together and applying a common input, or (b) pulling one input high with a pull-up resistor to +5 volts and using the second input for the input signal. A look at Figure 6 supports this claim.

Similar techniques can be used with a NOR gate (both inputs tied together or one input tied to ground) or an exclusive OR gate (one input tied high) to obtain the inversion function as well.

So, a good digital designer uses a little Boolean algebra, a little pattern recognition, and knowledge of basic gate substitutions to build simplified, cost-effective circuits. Even though these techniques, and many others, may be automatically applied by software in a digital-design package, it's worthwhile to understand them and be able to use them. Not all digital circuits require programmable logic devices, but they all need simplification. **NV**

About the Author

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

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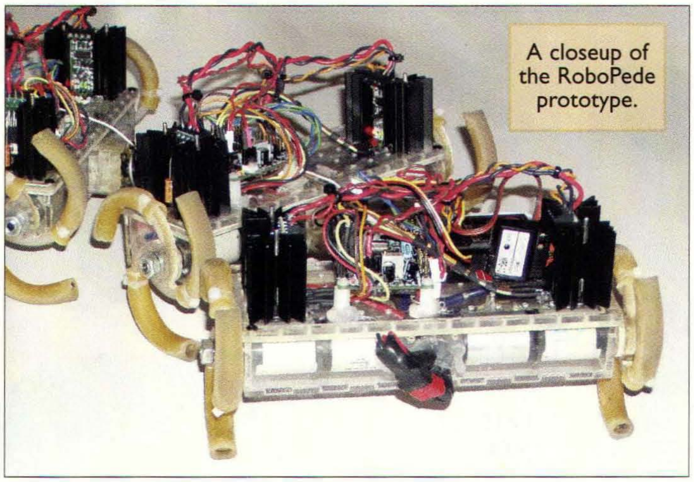
Understanding, Designing, and Constructing Robots and Robotic Systems

Personal Robotics

Robotics as an Art Form

I treat my robotics projects as free-form art more than engineering. In my professional career as an electro-mechanical systems engineer, I bury myself in spreadsheets and CAD programs — calculating, permutating designs, and evaluating. My prototypes must be as good as the finished product, and rarely vary much from the final product. In short, I'm very constrained.



A closeup of the RoboPede prototype.

But when I get home at night, I cannot help but continue with my interests. Here, they take on a much less regimented form — I relax and allow my creative juices to flow. The tedious attention to every detail of work is replaced with the joy of play. I explore, experiment, and really just follow my intuition.

The RoboPede I described last month is such an example. To recap, RoboPede is a 12 motor, six processor, centipede-like robot. The body is divided into six segments. Each segment has its own processor, a pair of motors, and associated H-bridges. Control between segments is provided by CANBUS. All together, the six segments make a 36-inch long, 12-inch wide, 12 lb. centipede-like creature.

Goal Seeking

When I decided to build this contraption, I had a certain goal in mind. I had a pile of motors from Escap, and new IsoPod™ from New Micros, Inc. — I wanted to use all of the timers, PWM, and analog of this board. The 12 PWM outputs could be used to control motor speed. The timers provided a way to measure motor speed. So the IsoPod and 12 motors were my starting inspiration.

What could I do with 12 motors? I knew that simply slapping that many motors onto a stiff chassis would be uneventful. Of course, I also wanted to build something unique. How could 12 motors be useful in driving a robot? The body would have to be something other than rigid. I came upon the idea of a segmented design.

My intuition immediately told me there would be something "pleasing" and potentially useful about a centipede design. The motion should be very animated — almost life-like. The idea of segments — all driving for the same goal — held an unstated promise. I couldn't express in words what I expected, but I knew it was a kinetic form that I wanted to explore.

A Joint Effort

The key to building this centipede properly would be the mechanical joint between segments. I had fretted over the design for quite a while, and I wanted my first attempt to be relatively simple. I wanted to allow the device to have relatively free pitch and yaw, and limited roll. I came up with several different ideas, each one seemingly more complicated than the next.

An exploration trip to the hardware store was the inspiration I needed. Sprinkler "cross" joints turned out to be a very close match to the bodies of my motors. With a little machining, the motors could be pressed in. The real gem from my looking around was the springs I found, which fit into the sprinkler joints with a little forcing. The springs were made of heavy wire, and allowed the segments to move just the way I wanted them to. The idea of the body came together.

Ideas From MIT

Now, what should I put on the ends of the motor for "motivators?" The right thinking about hubs and wheels eluded me for a while, too. I had seen "whegs" on an MIT website, and decided I would give them a try. "Wheg" is a contraction between wheel and leg, and is essentially three sticks stuck into a hub. I did some speed and torque calculations in my head based on the mass of my motors and batteries, and had some whegs laser cut out of polycarbonate.

I mounted them on the motor shafts and they looked good. I figured

I should make a test run of the chassis without adding microprocessor control. I assembled the RoboPede with a mass of tape, wire, glue, batteries, and an on/off switch.

Launch day proved to be a raving success. The beast performed better than I had expected. The thing was able to climb up and down stairs, over concrete parking blocks, through dirt ... whatever. It was unstoppable!

Kryptonite for Whegs

Well, almost unstoppable — crabgrass proved to be its undoing. I had designed a short arc onto the end of the wheg, in an attempt to provide a smooth rolling surface, a sort of trade-off between peg and wheel — to be more wheel-like, and less peg-like. In retrospect, I was unintentionally making hooks. As it turns out, these dug into the crabgrass and locked in. I could hardly pry the thing out of its self-woven green bed. If I had more torque available, I was sure I could use this as a garden implement. As it was, I had invented electric VELCRO®.

Once back on harder surfaces, I learned the choice of whegs meant vibration was going to be my enemy. Because this was a test bed, I knowingly did not follow good design practices. Not only should you not mount a side load to the shaft of a gearbox (unless it is specifically designed for that), but you should also support it by its provided mounting points. I did neither. I affixed whegs to the shafts. The shaft was attached to the gearbox, and the gearbox was supported by the motor, with the motor wedged into the sprinkler cross section. I knew it was wrong, but I had a surplus of motors, and didn't mind wasting a few to get answers. I only expected it to work for a few hours — tops.

Acceleration figures would likely reveal some frightening numbers, but hey, this was for fun, remember? Caution went to the wind. I did not expect things to go so wrong so quickly — some of the pins that held the gearboxes to the motors worked their way out, spilling sun and planet gears all over the place.

Clearly, a complete mechanical re-design was in order. I was going to have to support the gearboxes by their end plates, as was intended by their design. This was the end of the cheap and simple sprinkler cross sections.

At least I had a better idea of the hardware elements I wanted to embed. I set to doing a complete re-design of the mechanism itself. In this iteration, I would face-mount the motors, but I would not go through the trouble of isolating them with gears or belts and shafts. The added expense at this point would not justify it. I came up with a design that would encapsulate the motors, batteries, and wiring harness in laser-cut polycarbonate boxes. This design allowed me to access the computing hardware, while maintaining the "spirit" of the original design. I also took a meager step at the vibration and crabgrass issue. I designed my whegs as spiraling arms, with a neoprene sheath. I hoped this would act as a bit of a shock absorber.

Practical Wiring Considerations

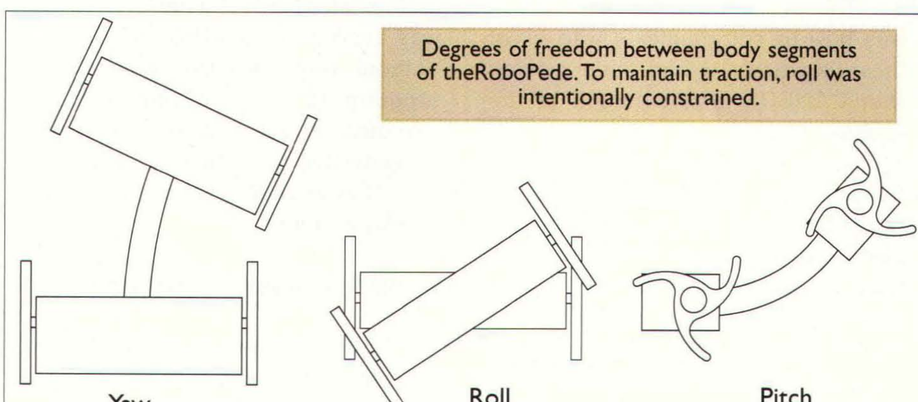
From a wire harnessing point of view, 12 motors offered a unique challenge. At the least, it meant a lot of stuff — no matter what it was. A lot of wire, connectors, batteries — you name it, there was going to be a lot. Early on, I decided I was going to run velocity feedback on every motor. Upon looking at all of the wire required, I decided to regroup my thoughts. First, there were a lot of control lines. Stringing motor power, +5V, ground, and signal wires to every H-bridge circuit meant a lot of wire. To top it off, stringing the error and tachometer lines back to the IsoPod amounted to even more. Realize that with 12 motors and bridges, you would be asking for trouble if you did not follow proper power practices, and use a star point ground and power distribution.

Now remembering what I said about work versus home, when I do a personal robotics project, I go with a sort of "free form" approach. If this had been a professional project, I would have modeled the harness from the beginning, and realized it was a major hurdle. But collecting a bundle of wire isn't that much fun, while building a robotic centipede sure is.

So here I was, with a neat idea, and a really tough build. Professionally or personally, I try to never let myself get locked into a faulty design, and this case was no exception. It would mean a major departure from my original design inspiration, though.

The solution was to go with a distributed processing architecture. Although it was a departure from my original intent, the details of distributed processing also presented a lot of challenges and left open some unique possibilities. For one thing, switching from one IsoPod to six MiniPods™ meant that I would lose *a lot* of wire. I would also have 40 more analog channels available, and could use a different control model for the motors.

In my original scheme, I had



Degrees of freedom between body segments of theRoboPede. To maintain traction, roll was intentionally constrained.

Getting the build complete took a lot of time. The very thought of all that wire, and all those components was daunting. After the mechanical build, I let it sit there on a shelf for a month or two. Finally, I forced myself to finish it, so I set out to get it all wired up. After about 40 hours worth of evenings, it was all wired up. I soldered and heat shrunk all the joints, used silicone insulated wire, and set it running.

This version, with the modified whegs, had slightly poorer performance, since less torque was available for accelerating and climbing. However, it was still fast, and a real challenge to catch. Remember that even on flat ground, it is climbing a hill three times for every rotation of the wheg. Bear in mind, the wheg isn't round. Unlike a wheel, the missing spots between spokes don't support the body. This amounts to climbing up a 1/2-inch hill, from supported to dropping, eight times a second. It was like designing speed bumps into my wheels.

intended to run the H-bridges with what is called locked anti-phase PWM. Since locked anti-phase only requires one wire to implement, it was a perfect match since I only had 12 channels of dedicated PWM available on the IsoPod. With six channels of PWM available per segment on the MiniPod, I could use what is called complimentary pair PWM. This would use two wires per H-bridge, but it offers better control of the motor. In addition, having four timer channels available per segment, I could now run quadrature decoding if I wanted to, reading position, direction and speed, instead of just simple unsigned-velocity feedback.

It's All About Communication

The missing piece of the puzzle was how to communicate with all of these segments. I had been playing with CANBUS, and although at the register level it is a bit esoteric, the simplicity with which messages are handled was quite appealing. CANBUS takes care of the boring stuff like message verification and error detection, leaving the fun stuff like higher layer protocols. Rather than spending the money to buy a specification for an existing CAN protocol, I decided I would write my own simple protocol.

RoboPede's maiden voyage was executed without velocity feedback. I had left room for the Hall-effect sensors with small magnets mounted on the whegs. I had intended to use these as rotation detectors, but I was too eager to play, so I delayed their implementation. I programmed a sort of "figure eight" pattern, and let it run loose. Even with the bigger whegs, and resulting reduced performance, it was about impossible to catch. Without more sophistication in the program to communicate with the operator, it was daunting to stop. Imagine this thing, a yard long, running "figure eights" at just under two miles per hour?

Power and Control

I had intended to implement an R/C transmitter and receiver later on, but it was clear that I needed to control it now. Implementing the R/C was fairly straightforward. I added the R/C receiver to the lead segment's computer, and used it to override the motor speeds. I used two timer channels to read my R/C receiver with the MiniPod, and had possibly the world's coolest R/C toy.

Actually, in robotics, it is perfectly valid to implement a simulator, or at least, that is what I keep telling my wife. Implementing the R/C has actually been a real help in understanding what it can and cannot do. This has allowed me to precisely control its behavior and observe what is happening. I had modeled differential steering in spreadsheets, and so applied simple mixing to control the motors by side. I also added reversing on the steering, so by pulling or pushing on the stick, it would go forward or reverse. The catch is that by going in reverse and flipping the steering, you could actually treat the tail as the head. I plan on using the third channel to cause a slight velocity gradient from front to back to help stabilize the rear end. (Eventually, I would like to add telemetry feedback that I can pump into LabView running on my PC.)

I had planned on some fairly sophisticated programming, as far as relaying commands to the different segments. I had intended to delay commands to the segments so that they would "wagon train" along. As it turns out, the mechanism takes care of that itself. Simple differential steering was apparently all it would take to make a reasonable system. This makes the control easier, but was disappointing in a way. I was looking forward to implementing a sort of bucket brigade to hand commands from one segment to the next. My individual segment control is warranted, however, because climbing requires specific control of the motor segments, which I will enable in the future. My current plan is to force one end to drag a bit, and tension the entire robot to prevent it from bunching up. I also think that I can gain a lot with advanced traction control, as well. Again, it is just part of the learning process.

Another planned use for the CANBUS is I/O. I have constructed some high current LED driver boards for red/green/blue and white lights on each segment. I can easily drive 40 LEDs per segment. As it is, all the 70 or so status lights on the MiniPods and H-bridges make for a stunning visual display at night, and having another 240 high intensity LEDs pulsating and flashing will be quite a sight indeed. I like to justify these as "status" lights, but honestly ...

Signs of Abuse

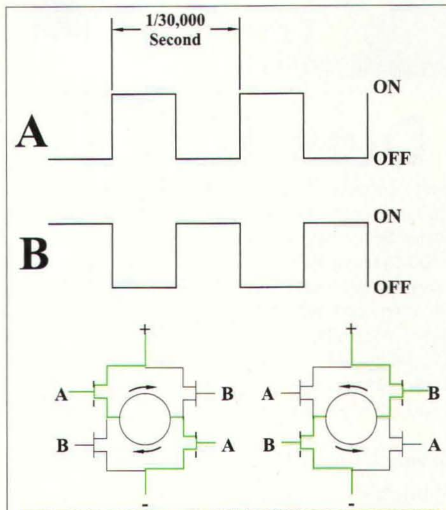
After many hours of runtime, everything was really getting beat up. The constant hammering of the whegs started causing solder joints to the batteries to come undone, connectors to come off, screws to come loose, and even glued joints and whegs to break. Some of this was expected, and I wrote it off as the "cost of doing business." After all, this is the electrical test-bed, meant to flesh out control issues, and be easy to program and modify.

Another unfortunate side effect was all of the bouncing. The constant hammering left me with very little sensing capabilities. With that much motion, I would either have to sense the motion and use it as a sort of scanner, or sense it and remove it mechanically. I looked at implementing a leveling platform, but that was an added layer of complexity I did not want to tackle.

If you look at MIT's whegged robots, you will find that they are mounted to rigid platforms. This, combined with positional feedback, allows them to synchronize the stepping of the whegs, which adds to their stability. As a whole, the platform is very stable. This realization caused me to completely abandon the whegs altogether. While it was an unfortunate eventuality, I had prepared for that, and had purchased a dozen polyurethane scooter wheels on sale at a local surplus store.

So, as a precautionary measure, I silicone glued all the connectors, boards, batteries, and mounted the wheels. The ride is now smooth, and I have about 20 hours on it since the repairs. It has also resulted in triple the battery life, and now I can easily run for 40 minutes between charges. A side benefit is improved climbing and guidance. Presently, it can climb up a city street curb with little effort.

Again, more trade offs — before, the random hopping caused it to have sometimes wild lateral excursions while moving forward. Now, the front-end tracks in a straight line. Unfortunately, it is less life-like than before. The hopping gave it an endearing quality, but I cannot afford the time for the repairs. When I do another one, I will factor the vibrations in, and account for them.



The H-bridge control technique used on the drive system. The motor only reacts to the smoothed average of the duty cycle presented by the A and B phases.

Dynamic Control Questions

Of course, there are side effects that have cropped up that I don't fully understand yet. The rear wheels now tend to "fishtail" fairly severely. This is at its worst on smooth linoleum, and not noticeable on low plush carpet. I believe a few things could fix this. One would be positional encoding on the segments. By giving a segment a trajectory to follow, it cannot allow itself to get "bullied" by other segments. Another possible remedy is to allow the rear-most segments to "drag" behind, or perhaps the advanced traction control will solve things.

After testing all the different software ideas I want to explore, I will most likely build one last mechanical version. In this version, the electronics will be encapsulated, and any mechanical flaws will be corrected. At this stage, I would like to have vacuum-formed cosmetic body panels made, with backlighting provided by my LED boards. Belts and axles will isolate the gearboxes from the loads, and will even give me some finer control of torque versus top speed.

I will most likely switch from hand-wired discreet transistors for the LED drives to some high current drives on PC boards, integrated to carry the H-bridges for the motors and MiniPods, as well. I plan to implement my "optical mouse hack" as a primitive vision sensor, combined with an array of infrared distance sensors. I may even increase the mechanical platform's size to include more batteries and encoded gear motors, and perhaps a music playback device to play the theme from a well known parade at a well known theme park.

Overall, the RoboPede saga has only just begun. Every discovery leads to more questions and interesting solutions. It still pretty much looks and acts like I intended, although I really expected I would have to provide a much more active software control system.

At this point, I am running without feedback on the wheels, yet I climb curbs, stairs, and children with relative ease. I do know that getting it to understand terrain will be difficult, but hey, it has always been about the challenge.

It's about "art" done my way. **NV**

Comments/Questions?

Mike Keesling can be contacted through Email at author@bio-bot.com

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Electronics Q&A

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, as well as comments and suggestions.

You can reach me at:

TJBYERS@aol.com.

What's Up:

It seems I struck a cord on more than one answer from the recent past: readers who want more in depth info on topics I touched on. This month I honor those requests. The most requested is expanding on earth ground and the equalization of records cut before RIAA. The second most asked are answered via tutorials: the 4N25 optoisolator, 555 timer, and Wi-Fi. Finally, a quiz for you, the reader.

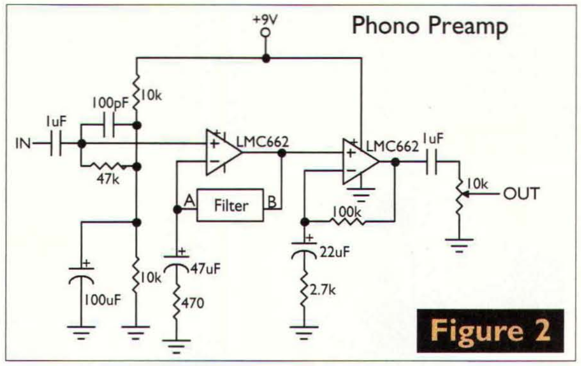


Figure 2

Equal Opportunity for Vintage 78s

Q. Your published answer for a phono preamp is nearly perfect for my needs. However, the bulk of my record collection is acoustic 78s, cylinder records, and Edison Diamond Disks, none of which would benefit from RIAA roll-off or pre-emphasis. I have all the hardware necessary to play my records, and the software to remove the clicks and hiss, but I need a way to switch out the RIAA curve, and a way to adjust the volume into the Line In port of my sound card. The volume level on the ancient recordings varies tremendously. Can you help me?

Wm. Motley, NV19742
via Internet

Q. I really appreciated your circuit showing a phono preamp in the Aug. 2003 issue. It's exactly what I wanted. However, my father has a lot of old 78s that I tried recording on CD and discovered they sounded either too bassy or just plain flat. As a kid, I remember my father having a tube preamp that had a selector switch that he would twist until the record sounded right. Was this a real feature or just a bell/whistle money grabber?

Thomas
via Internet

A. No. It was real. Many of the earlier 78 RPM recordings had equalization (unlike the acoustical recordings of Wm. Motley). The problem is that there was no standard at that time, and every label made up their own equalization curve. The RIAA standard wasn't introduced until the LP came along in the '50s. Figure 1 shows equalization filters for five popular 78 RPM curves, plus a straight through "filter" for those Edison cylinders. Simply insert the proper filter in the phono preamp feedback loop (Figure 2) for the medium you wish to play back and you're in business. The output volume is adjusted via the 10K potentiometer.

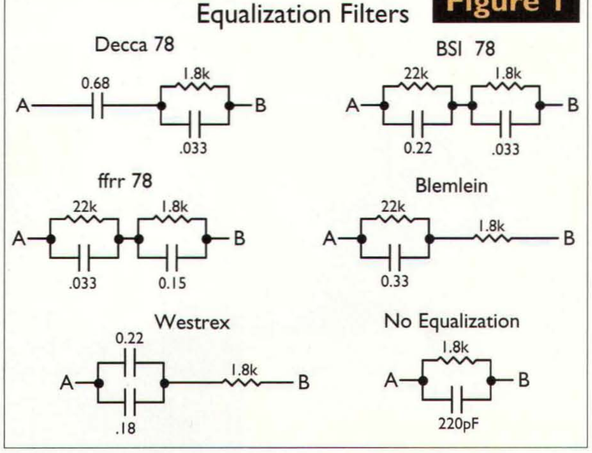


Figure 1

4N25 Tutorial

Q. I am interested in knowing how to use the 4N25 optoisolator. I thought I understood how these things are suppose to work, but I don't seem to be having any luck actually using them in a circuit. My problem is simple — isolate a computer parallel port from a low-voltage on-off controller (less than 20 volts).

I found a circuit that connects the parallel port to pin 1 of the 4N25 through a 100-ohm resistor. Pin 2 of the 4N25 is grounded. On the other side of the 4N25, Vcc goes to pin 6, and pin 4 is grounded through a 1K resistor. Results: a hot 4N25. Another circuit (right off a spec. sheet) shows the Vcc going to pin 5 while pin 6 is grounded. The output is on pin 4, which is grounded through a 1K resistor. Results: nothing. Please explain how to make this work and what is wrong with the above setups.

James A. Tadlock
via Internet

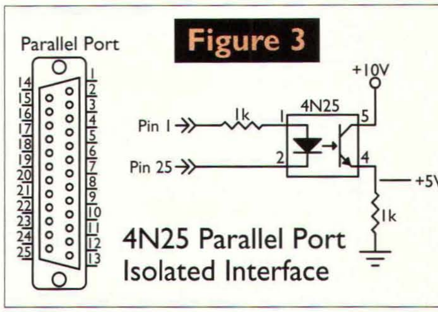
A. First, you have to remember that the 4N25 is really two, two, two devices in one. The first device — the input — is an infrared (IR) LED. The output device is an NPN transistor — nothing more, nothing less. And, as an NPN transistor, you have to treat it as such. The collector (pin 5) has to go to +Vcc and the emitter (pin 4) has to go to ground. Somewhere inbetween is a resistor to limit the current to prevent destruction of the transistor and develop an output voltage (Electronics 101).

The current through the transistor's base (pin 6) determines how much current flows through the collector and emitter. In the case of the 4N25, the base current is determined by the amount of light produced by the input LED. In almost every 4N25 circuit, pin 6 should not be connected to anything — listen, not anything (i.e., left dangling). The base current is exclusively controlled by the intensity of the light falling on the photosensitive NPN transistor. On the LED side, pin 1 has to go to +Vcc and pin 2 has to go to ground. Again, a current-limiting resistor has to be placed in series with the LED so that it doesn't burn up (Electronics 101).

Now, back to your question about interfacing the 4N25 to a PC parallel port. Refer to Figure 3. Starting on the port side, it connects to the LED. For the sake of argument, let's pick pin 1 as the signal line and pin 25 as ground (GND). The LED is wired so that the anode (pin 1) goes to the signal line and the cathode (pin 2) goes to GND (don't forget the current limiting resistor). The NPN transistor is wired so that the collector (pin 5) goes to Vcc (less than 30 volts) and the emitter is grounded through a 1K resistor.

When pin 1 goes high, it will light the LED and turn on the transistor which, in turn, produces a voltage across the 1K resistor. The amount of voltage depends on the current

Figure 3



4N25 Parallel Port Isolated Interface

through the LED. Most of today's 4N25s have a 100% transfer ratio. That means, 10 mA through the LED will allow the transistor to conduct 10 mA. But here you have to be careful, because some older 4N25s only have a 25% transfer efficiency ratio (10 mA in equals 4 mA out). Another gotcha is the output current of the parallel port. Most are spec'ed at 5 mA per pin, but that can vary between 4 mA and 10 mA, depending on the driver chip the PC uses. The values in Figure 3 are designed for 5 mA in and 5 volts across the output resistor with a Vcc of 10 volts.

As to why your circuits didn't work, in the first example you were running a lot of current through the base of the transistor, causing it to heat up. In the second, where you grounded the base per the datasheet, this is a test configuration the factory uses to measure leakage current through the transistor, and isn't a working design.

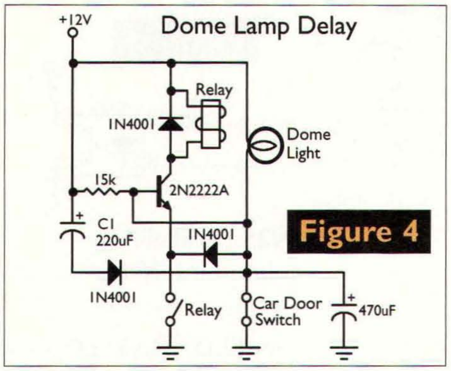


Figure 4

Turn Out the Light, Please

Q. I have an older car and would like to be able to have the dome light stay on for 5 to 10 seconds after the door is closed. Can you show me a circuit that I can possibly build into the dome light for this?

C. Ritchie
Elk Mound, WI

A. When you say older car, I have to assume that the light is hard-wired to +12 volts and that the door switch breaks the ground connection. This is the common wiring configuration for virtually all models before 1980, where the dome light is grounded when the door is open. If this is the case, then the circuit in Figure 4 is the solution.

In this circuit, capacitor C1 is initially charged when the light turns on — that is, grounded. Notice that the relay contacts are across the door switch. You do this by attaching one relay contact to the ground side of the dome light bulb and the other to any metal part of the car frame (easily accessible at the roof, just don't drill holes through the roof!). When the door is closed, and the door switch opens, the relay maintains the ground connection as C1 discharges through the 15K resistor. When the current through the relay falls below its hold current, it drops out; the light goes out and the timer stops, drawing no further current from the battery.

Adjusting the capacitance value of C1 will lengthen or lessen the relay drop-out delay time. Because you want to place all the electronics in the dome assembly, I suggest using a reed relay like the RadioShack 275-233, in which case the diode across the relay isn't needed.

555 Tutorial

Q. You had several good circuits in the Sept. 2003 issue, but one that specifically caught my eye was "At A Crossing." As an experiment, I built the "LED Flasher" (Figure 2). When I replaced the 220K resister with 1 Meg, and the 1 µF capacitor with 10 µF, I was really happy with the timing. My problem is that what I really need is the ability to vary the duty cycle of the LEDs (shorten one and lengthen the other). Ideally, I'd like to go from 0% to 100%, however, something like 10% to 90% would do just fine. I've begun to believe that a 555 may be designed specifically for 50%, and therefore, not be good for this.

Calvin Hirmke
via Internet

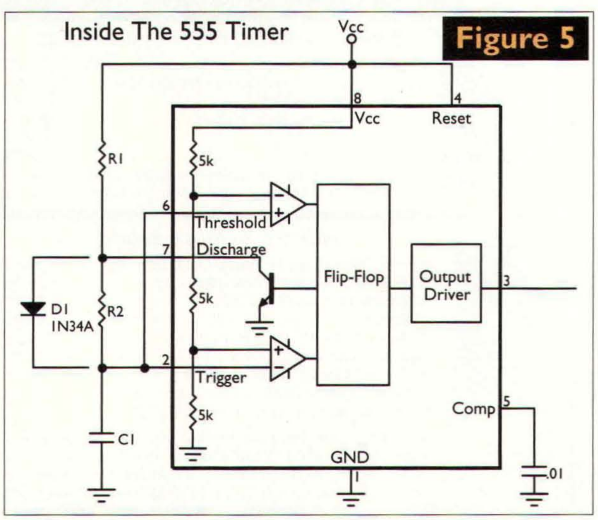


Figure 5

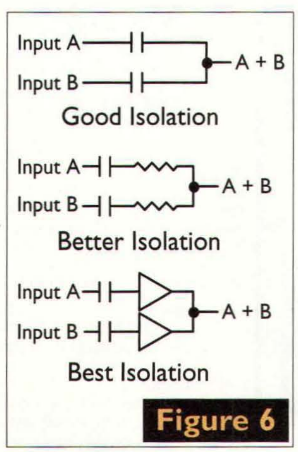


Figure 6

A. Actually, the duty cycle of the 555 is determined by the ratio between the two timing resistors, R1 and R2 (Figure 5). Inside the 555 is a level-triggered flip-flop. That is, when the voltage across C1 exceeds 2/3 of Vcc, the output (pin 3) goes high and when the voltage across C1 drops below 1/3 of Vcc, it goes low. The charge path is the combined resistance of R1 and R2 — the discharge path is an NPN transistor inside the 555 (pin 7) only through R2. When the value of R2 exceeds R1 by more than 10 to 1, the output is, for all intents and purposes, a square wave.

Here's a nifty way to experiment with different duty cycles: Place a diode across R2. This allows C1 to charge through R1 and R1 only. The discharge path is still through R2, but now the resistors are independent of each other, which simplifies the math. Instead of having to juggle five values, the equation is reduced to: Duty Cycle = R1/R2. I suggest using a germanium diode, like the 1N34A, instead of a silicon diode to reduce the timing error caused by the voltage drop across the diode.

Mix it Up

Q. In your Sept. 2003 column, you offered a subwoofer filter to Stan from Florida. May I ask a question about that schematic? The right and left channels are summed, each through a 4.7 µF cap, to a high-impedance point at one end of the 220K resistor. Won't this compromise the separation between the two channels? Couldn't this loss of separation be avoided by running each channel through a separate series 4.7 µF cap and 220K resistor and summing them at the zero-impedance point at the inverting input of the LF353?

Mike Byrnes
via Internet

A. This is a common question, and a common misconception about signals that need to be mixed. In my design, the right and left signals are driven by two strong low-impedance sources (the aux outputs), so there is no possibility of the two feeding back through these outputs. On the other hand, this would not be the case if I were trying to design an audio mixer panel with four high-impedance sources (like a microphone) where one input could create crosstalk on the other. The "back-path" mixing of these signals would be disastrous. So what to do?

If you want a mixing of signals, usually at the same volume level, then use the simplest mixer (a.k.a., caps), like I did. If you want to have complete control over the volume of each and every input without it affecting adjacent channels, a buffer is required. Simple, huh? No? Maybe this diagram (Figure 6) will help.

Earth Ground — Revisited

Q. I was just reading your "Earth Ground" answer in the July 2003 issue, and near the end of your first paragraph, you say "it's important to know the resistance of the soil and treat it with chemicals if the resistance is too low." Didn't you really mean too high? I have never seen anyone desire a high ground resistance.

Tom B. Jones, III CPBE CBNT
Montgomery, AL

Q. Regarding the "Earth Ground Tester" in the Jul. 2003 issue, what chemical do I use if the resistance of the ground is too low? And how do I know if it's too low?

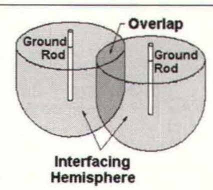
Bob E.
via Internet

A. Alright, already. I confess that I made a typo error while editing my own writing (who doesn't?) So let me set the record straight. You actually want the lowest ground resistance possible. While values of 10 ohms or less are standard practice in commercial codes and long haul communications systems, the recommended IEEE practice is to provide a resistance of less than 25 ohms for any earth ground electrode. A ground electrode normally consists of a metal rod (typically copper or steel) driven into the ground; the length of the rod is usually in the 6 to 10 foot range.

However, local soil conditions will affect this target figure. In some regions, a resistance of 10 ohms or lower is easily obtained using a three foot rod, while in other regions, it may be difficult to bring the resistance of a driven ground under 100 ohms. The first urge is to drive the rod deeper into the earth, but beyond 10 feet, the change in resistance becomes negligible. For example, to reduce the resistance of a 10-foot rod to half its value requires extending that rod to 100 feet in the same soil. A better solution is to increase the number of ground rods.

A ground rod creates an interfacing hemisphere in the earth surrounding it. The diameter of that hemisphere is approximately 2.2 times the length of the rod. When more than one rod is required, they should be spaced no closer than 2.2 times the length of that rod in any direction. If multiple rods are driven too close together, the rods don't have a complete interfacing hemisphere, and the effectiveness of those additional rods are reduced proportionately. To illustrate, consider Figure 7. If we assume that one 10-foot rod provides a resistance to earth of 100 ohms, then 10 rods spaced five feet apart reduces the resistance to about 28 ohms. At 10-foot intervals, it's about 18 ohms, and at 22-foot separation (2.2 times their length), it's down to only eight ohms. Notice that there are the same number of rods, but with considerably lower resistance when they are properly spaced. Peppering of the property with new rods is okay, as long as you follow the 2.2 rule.

But even this solution has its limitations. An obvious limit is reached when you run out of acreage for extra rods. To reduce the ground resistance, either more land is required or the resistivity of the available soil must be lowered. Soil resistivity can be lowered through chemical treatment, like copper sulfate or sodium carbonate. The type of chemical and amount depends on the soil, which changes from place to place. Check with your local environmental laws for details on approved soil conditioners for your area.



Avoid Ground Rod Overlap

Figure 7

A 555 Reader Quiz

Q. I'm looking for a countdown timer circuit that, when a start button is pushed, will blink an LED on/off every second for 10 seconds. I also need a manual reset. Do you have a simple circuit for this?

C. Ritchie
Elk Mound, WI

Cool Web Sites!

Wireless networking is becoming increasingly important to businesses and home users. Confused by terms like Wi-Fi, Ethernet, or Bluetooth? For answers, check out the following.

Wireless networking FAQ
www.vicomsoft.com/knowledge/reference/wireless1.html

Wireless communications chart
www.homenethelp.com/802.11b/index.asp

Ethernet tutorial
http://chipcenter.com/circuitcellar/march02/c0302ts1.htm

Wi-Fi (802.11b) tutorial
www.homenethelp.com/802.11b/index.asp

Bluetooth FAQ
www.palowireless.com/infotooth/

ZigBee — the new kid on the block
www.chipcenter.com/knowledge_centers/wireless/product_review/showArticle.jhtml?articleID=13100643

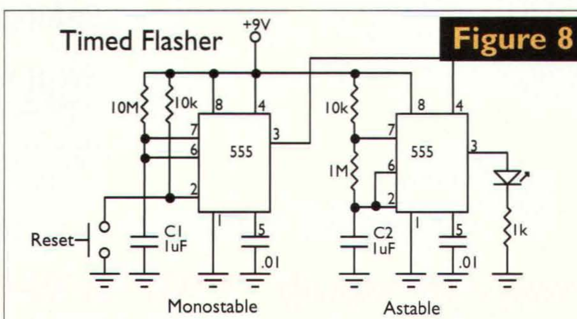


Figure 8

Q&A

A. I'm surprised at how versatile the 555 chip really is. It has solved more than a few sticky problems. Again, this is a not-so-unique case. Remember, the 555 can be configured as a monostable (one shot) or astable (free running) oscillator. What we need here is a monostable circuit, with a 10 second time-out, and an astable oscillator running at 2 Hz. If you haven't already figured it out for yourself (yes, this is kind of a quiz for those readers who think they know the 555), then here is the answer (Figure 8).

The trick to this circuit is the Reset input (pin 4). When it's high, the astable oscillator oscillates; when it's low, it stops. The output (pin 3) of the monostable multivibrator determines how long the astable stage is allowed to run by pulling the Reset pin high for a time determined by C1. C2 establishes the flash rate of the LED.

Now a question for you, dear reader. How would you simplify this design even more? Being able to easily vary both time periods individually is a plus. PIC and StampBasic solutions will be considered, but only if there's ease of operation and the code is tight. I will print the winning entries in an upcoming column.

MAILBAG

Dear TJ,

Maybe the third time's the charm, but the schematic on page 38 for "The Winner Is" circuits needs the diodes reversed. As Brad Lieffring pointed out in his letter (Sep. 2003, page 39), diodes will prevent multiple lights when the winner's switch is held down. But with the diodes as shown, no one will ever be able to "win."

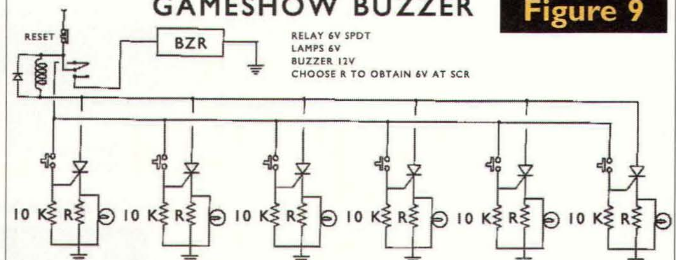
Joe Turner
via Internet

Dear TJ,

Kudos for your very informative answers to our electronics problems — a must-read section for me. After poring over the Gameshow Buzzer diagram, though, I fail to see how adding diodes would solve the backflow current which does occur when a contestant holds the button down. The attached circuit (Figure 9) is my humble offering that uses SCRs and only one relay. The SCR performs the necessary latching action and turns on the relay thereby turning off all the contestant's push buttons and turning on the buzzer and the winner's light.

James Drake
San Francisco, CA

GAMESHOW BUZZER **Figure 9**



Micro Memories

Before there was the Web, there was CompuServe

Looking back, 1979 was a watershed year for online services: CompuServe opened up to the general public, and so did The Source, its chief early rival for national online PC services (and eventually acquired by CompuServe in 1989). And the first local BBS (computerized bulletin board system) went online that year in Chicago, IL. While a few BBSs have survived by converting to Internet sites, The Source is long forgotten. Only the CompuServe name exists today, as a pale, America Online-owned shadow of its former self. But it played an important role in offering millions their first glimpse of online services available through their personal computers.

Putting a PDP-10 to Work

CompuServe's history begins 10 years prior to 1979, though. Curiously enough, it began the same year Arpanet (the Internet's predecessor) first went online (CompuServe's history — and fate — would of course, be intertwined with the Internet). An Ohio-based life insurance holding company named Golden United Life Insurance Co. purchased a million dollar Digital Equipment Corporation 36-bit PDP-10 mainframe to crunch their numbers and process their data. The company was run by a gentleman named Harry K. Gard. His son-in-law, Jeffrey Wilkins, and Wilkins' grad school classmate John Goltz, convinced Gard to sell excess computing time on the mainframe to other companies. This service was first

When 1.77 MHz was fast — a Model I TRS-80.

dubbed "Compu-Serv," and began operations in October of 1969.

Back in the late 1960s and early 1970s, this was a fairly common practice, as computer users at corporations and universities would frequently dial in and timeshare mainframes at night. It put the mainframes to work during off hours, when the companies otherwise wouldn't be using their expensive investments. This is where CompuServe, as we know it today, really began.

During the 1970s, "Compu-Serv" expanded their services to business users, and by 1972, had over 400 accounts across the country.

The ever stylish PDP-10.

Simultaneously, the first personal computers were being built, initially by hobbyists and later as fully assembled units by MITS, RadioShack, Apple, Commodore, and others. Eventually, dial-up modems were offered as accessories for those PCs, and services such as CompuServe and The Source, along with regional bulletin boards, began to spring up as destinations for Jurassic surfers.

MicroNET: CompuServe Meets the PC

In 1977, the name was officially changed to CompuServe Incorporated, and on July 1, 1979, CompuServe was ready to begin offering service to computer hobbyists, initially under the name MicroNET. Prior to its rolling out in July, MicroNET had been beta-tested for two months among the members of the Midwest Affiliation of Computer Clubs (sources vary as to how many members were involved in this test, ranging from 100 to as many as 1,200). The first services MicroNET offered online included message boards, databases, games, and Email. Shortly after MicroNET was offered to the general public, an Apple II special interest group opened, dubbed "MAUG," for "MicroNetted Apple User Group."

In 1980, with less than 2,000 consumers as members, CompuServe was sold to H&R Block for $22 million, who would quickly return to the original CompuServe trade name to promote their nascent online service. H&R Block seemed like a fairly logical successor to Golden United Life Insurance Co., and it was somehow appropriate that a button-down accounting firm would purchase a business started by an equally staid life insurance company.

A Snapshot of CIS in 1981

I belonged to CompuServe for a few months in 1981, when a trial offer came with the software for the 300-baud modem I purchased for my TRS-80. I don't recall much, except that I do remember CompuServe's sprawling version of the text-based Adventure game, and a few of the early forums, which in those days, were called SIGS, for special interest groups. As early as 1981, as the first Space Shuttle launches began, there was a NASA SIG. And of course, there was a TRS-80 SIG, along with the aforementioned Apple II, and groups for other computer users.

Capitalizing on the CB radio fad that had peaked just a few years earlier, there was an online chat section, which CompuServe wisely dubbed CB — thus, making CompuServe irresistible to anybody who had been involved in CB radio (as I had been). While it no longer is called CB, to this day, typing "GO CB" into CompuServe's GUI will take you into their chat sections. (Sadly, "GO ADVENTURE" simply 404s.)

CompuServe didn't go flat rate until October of 1997, shortly after AOL announced its plans to acquire it, and a full year after AOL announced their "all you can eat" monthly plan. But in the early 1980s, CompuServe charged by the hour and that time added up very, very quickly spending an evening chatting in CB. So for many, it was a taste of the future — and an expensive one, when the Visa bill arrived at the end of the month.

HSX Adds Sex to CompuServe

Despite their staid reputation, H&R Block took a fairly laissez-faire style when it came to allowing its CompuServe division to create its online content. Besides the technology-oriented SIGs, and online chat and games, CompuServe opened up one of the first online sexuality sites in 1983. It was founded by the husband and wife team of Howard and Martha Lewis, who previously had written several books on sex, health, and self-improvement therapy. Lewis had heard that CIS was looking for additional forum owners. He contacted CIS, explained his background, and a representative of CIS told him that they were looking to add either a general health or sexuality forum to the service, and that Lewis seemed to be qualified to run both. Lewis picked the latter, and shortly thereafter, HSX was born (and exists to this day — just type "GO HSX" into CIS's GUI).

CIS in the Go-Go 1980s

Still, despite the high initial costs for early adopters, by 1982, H&R Block was riding the explosive sales growth of the first personal computers, and grew CompuServe into a major player in online services in the US. Four years later, it entered the international arena, with an arrangement to develop a Japanese language version. In 1989, CIS expanded into Europe, where it developed a considerable hold on online users — particularly in Great Britain and

The CompuServe website as it looks today.

Before the iMac — an Apple II.

Germany. At its peak in the early 1990s, the number of CIS worldwide users was approximately eight million.

The 1990s: The End of the Line

CompuServe was eventually sold to AOL in 1998 for $1.2 billion, not too shabby a return on H&R Block's original investment. AOL has attempted to maintain CIS as a distinctive brand name, and initially marketed it as an alternative for small business owners and entrepreneurs looking to avoid the hijinks and cutting up over at AOL.

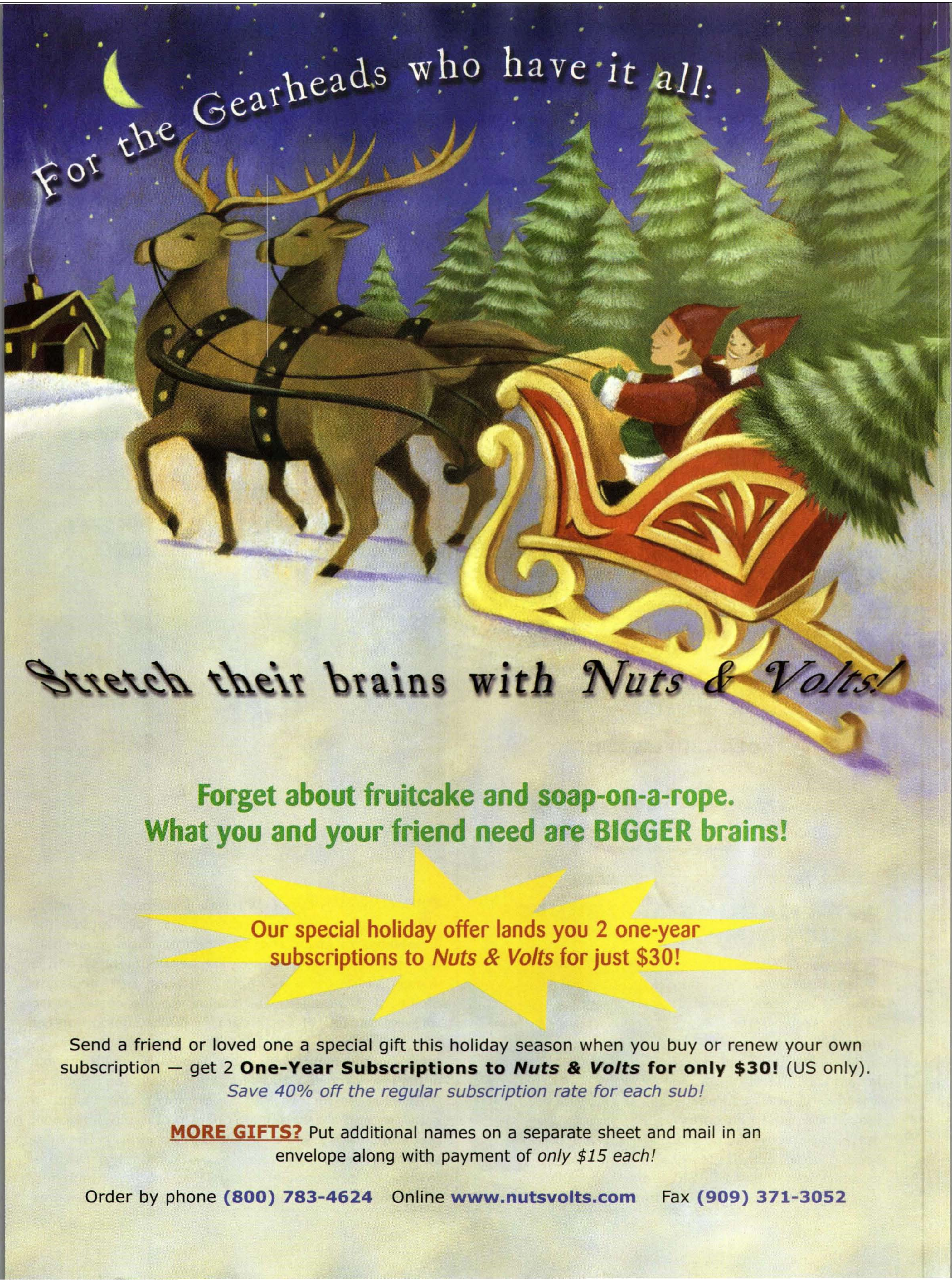
But, like Rome, the rot occurred from within — because CIS waited so long to go to a flat rate service, they lost millions of subscribers in the mid-1990s to AOL and even less expensive services. Today, CIS's membership numbers about two million or less, compared to AOL's claimed base of over 30 million members.

The shrinkage of CIS's member base continues to this day, as more and more realize that the $24.95 a month fees to belong to CIS's dial-up connection pales next to the wealth of free Internet sites available via a $49.95 cable modem or DSL connection.

But the pioneering spadework that CompuServe provided in the late '70s through the early '90s was invaluable-and provided millions with their first glimpse of the online world. **NV**

An acoustic coupler modem.

Images of the computers in this article are courtesy of *The Computer History Museum* **www.computerhistory.org**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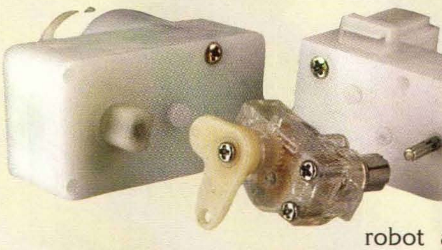
NEW ROBUST GEAR MOTORS



Solarbotics now offers an assortment of inexpensive, robust gear motors ideal for robot actuation and locomotion purposes. Most are available in either 90 degree or offset/inline shaft configurations, with integrated over-torque safety clutches.

The GM2 and GM3 offer a 224:1 gear reduction, with 50 in-oz stall torque, 38 RPM free running speed at five volts from an RA-130 style motor, and optional wheels or mounting hubs.

The GM8 and GM9 are similar in design to the GM2 and GM3, but with a 143:1 reduction, 43 in-oz torque, 70 RPM at five volts, and also accommodate the optional wheels.

The GM6 and GM7 are miniature versions of the GM2 and GM3, with a 120:1 reduction, 20 in-oz torque, and 145 RPM at five volts, with a splined steel output shaft.

The latest GM10 gear motor is a tiny one inch long pager motor powered unit with an 81:1 reduction, 1.2 in-oz torque, 375 RPM at five volts, and an easily-removed self-centering spring mechanism.

Visit Solarbotics' website for full specifications. OEM, wholesale, and retail interest are all welcome.

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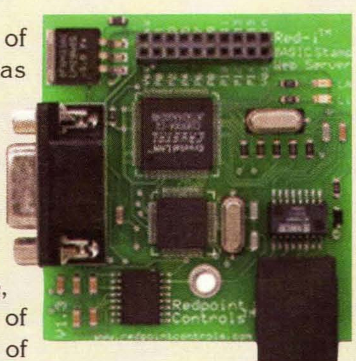
Circle #107 on the Reader Service Card.

WEB-ENABLING APPMOD FOR BASIC STAMPS



Redpoint Controls™ of Morgantown, WV has released the Red-i™ Basic Stamp Web Server to make Ethernet connectivity a reality for Parallax, Inc., BASIC Stamp users. Based on Redpoint's Red-i embedded Ethernet core, the Web Server is capable of hosting up to 100 Kbytes of web files and enables BASIC Stamps to update web pages and receive HTML form data through simple serial commands. The Web Server also enables Stamps to send SMTP Email messages, and implements UDP protocol for point-to-point communication with other Red-i Ethernet-enabled Stamps. Combined with other accessories from Parallax, applications include web-enabled home automation, high-powered industrial control, and interactive robotics. The Red-i BASIC Stamp Web Server is designed on the AppMod format for easy integration into any Stamp project.

The Red-i BASIC Stamp Web Server is available exclusively from Parallax and Parallax Authorized Distributors (**www.parallax.com**; 888-512-1024).

For more information, contact:

REDPOINT CONTROLS, INC.
866-473-3764
Web: **www.redpointcontrols.com**

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PROTOMETER MODEL PRO-88 DIGITAL ENGINE ANALYZER — MEASURES TACH AND DWELL

Global Specialties has just introduced a new, low-cost CAT III 600V rated hand-held engine analyzer.

This special engine analyzer with a backlit LCD Display comes *standard* with data hold, tach, and dwell measuring facilities for 3, 4, 5, 6, and 8 cylinder engines, DCV, DCA, resistance, temperature, diode, and continuity test ranges, as well as heavy-duty test and temperature probes and a heavy-duty cloth carrying case, at a price of only $49.95.

All functions and ranges are electrically protected to ensure safety. The complete specification sheet for the new model PRO-88 is available for download as a PDF file from the Global Specialties website.

Also available are downloadable specification sheets for other new ProtoMeter models, the new, *just released* Full Line Product Guide, and the name of a local Global Specialties sales representative or stocking distributor.

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STRIPLED® CONNECTABLE LED MODULES ARE THE BUILDING BLOCKS FOR TODAY'S CUSTOM LIGHTING APPLICATIONS

LEDtronics® announces StripLED® Connectable LED modules that make light work of configuring lighting solutions for channel and reverse-channel lettering, signs, displays, under-the-counter, and architectural applications. StripLEDs eliminate many of the shortcomings of neon or fluorescent lamps such as heat, broken tubes, and ballast failures. Each StripLED module contains four super-bright, wide-angle (85°) LEDtronics SpiderLEDs, one three-inch double-ended connector harness for easy daisy-chain assembly, and a pre-applied strip of 3M® double-sided foam tape for "peel and stick" placement.

LEDs are wired in parallel and function independently. If one LED fails, the remaining LEDs continue to operate. LEDtronics offers StripLED in five colors: green (525 nm), red (636 nm), yellow (592 nm), blue (470 nm), and white (7000 K). Red and yellow StripLED modules are 12 volts. White, green and blue are 14 volts. In addition to channel-letter applications, StripLED may be used in buildings, amusement parks, theaters, stairways, emergency exit pathway lighting, etc.

Solid-state design renders LEDs impervious to shock, vibration, frequent switching, and environmental extremes. With an average life span of 100,000-plus hours (11 years), LED lamps operate more than 20 times longer than the equivalent incandescent lamp. Savings from reduced maintenance costs and downtime quickly return the capital investment expenditure. LED lamps produce almost no heat and require 80%-90% less operating power than equivalent incandescents, making them as friendly to the environment as they are to the operating budget.

Prices for StripLED Connectable LED Modules range from $2.75-$3.80 each, depending on LED technology and color. Availability is stock, to four to six weeks for special requirements. StripLEDs carry a one year limited warranty. For additional information on how to incorporate StripLED modules into your product designs, contact:

LEDTRONICS, INC.
23105 Kashiwa Ct.
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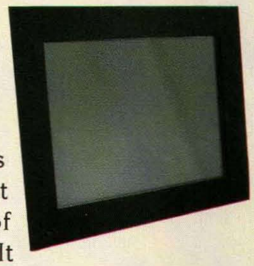
Circle #149 on the Reader Service Card.

12.1" XGA INDUSTRIAL-GRADE PANEL MOUNT LCD



Earth Computer Technologies has added a 12.1" panel mount monitor to complement its point of sale and kiosk LCD monitor line. It is constructed of a vandal resistant, ultra-thin metal bezel with a black powder coat finish, and it has a depth of just over one inch that facilitates easy, drop-in installation for surface flush mount applications. The PM-121 has wide viewing angles, vivid color reproduction, auto scaling, and field replaceable backlight bulbs. The PM-121 also includes a power and hard drive LED indicator incorporated into the bezel — ideal when the PC is remotely located.

The PM-121RT adds an optional four-wire industrial-grade resistive touch screen that is integrated within the bezel and connects to the serial port, operating via mouse emulation using a software driver. Impervious to scratches, moisture, and grease, resistive touch glass is commonly used in POS systems, as well as operator controls. Street price for the PM-121 with resistive touch is $529.00 and without touch is $329.00.

For more information, contact:

EARTHLCD
32701 Calle Perfecto
San Juan Capistrano, CA 92675
949-248-2333 ext. 223 Fax: **949-248-2392**
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Web: **www.earthlcd.com**

Circle #117 on the Reader Service Card.

by Thomas Scarborough

Wind-Up Flashlight

Crank up these LEDs

This Month's Projects

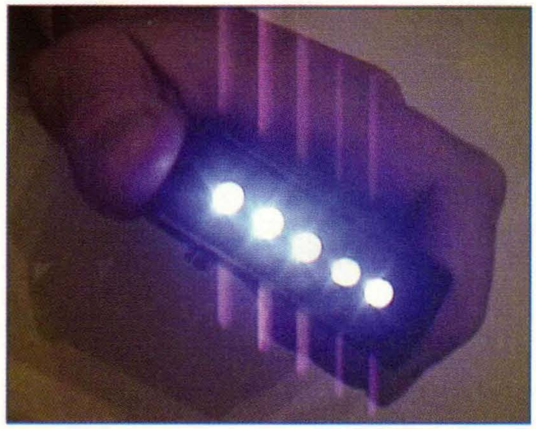
The Fuzzball Rating System

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 in each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!



I was staying in a remote part of the Fiji Islands, in the spring of 1994, and had planned to make it home on foot by nightfall. A major storm was looming, and a local commented, "Perhaps it's a hurricane?"

I set out on a track through the undergrowth — then darkness fell. I pulled a small krypton flashlight from my pocket and switched it on — it quickly faded and died. Then a truly terrifying storm overtook me, and I found myself lost in complete darkness. Thus, the idea for a wind-up flashlight was born!

Two earlier wind-up flashlight designs of mine have been published worldwide. However, unlike the present design, these emphasized extended use rather than brightness. With the present design, I aimed for brightness and simplicity. In regards to simplicity, the wind-up flashlight, on its case, has a single wind-up knob — nothing more — and internally, it uses only a handful of components.

The circuit has been balanced so that a regular, leisurely wind will keep it shining brightly using almost any small, unipolar stepper motor as the "power plant" or generator. However, when winding stops, the duration of light is short, therefore the flashlight requires continuous winding (see the side-bar for suggested modifications).

In contrast with other flashlights, my wind-up flashlight uses no batteries at all — not even rechargeables. The five white LEDs which are used should last hundreds of times longer than a filament bulb — and if a unipolar stepper motor is salvaged from an old floppy disk drive, printer, or scanner, the rest of the parts should soon pay for themselves through savings on batteries.

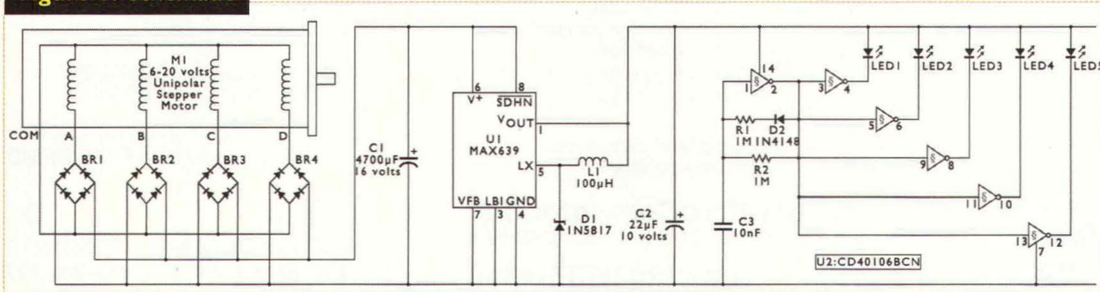
Power Considerations

At the heart of the Wind-up Flashlight is its "power plant" or generator, which may be almost any four-phase unipolar stepper motor between 6 and 20 volts. These usually have five leads, or six — and in rare cases, even eight.

In the case of five leads, one of these will be the motor's "common" lead. In the case of six, two will be the common leads. Since there is no standard arrangement for such leads, nor any standard color-coding, the leads are identified as follows:

- In the case of five leads, systematically measure the resistances across the various

Figure 1. Schematic



leads with a multimeter. The one lead which is consistently involved where the lowest resistance is measured is the common lead.

- In the case of six leads, the two common leads are usually located at the center of two rows of three. In the same way, measure the resistances across the various leads. In this case, two leads will consistently be involved where the lowest resistances are measured. These are the common leads. Ignore any measurements which show open circuit (infinite resistance).

The four AC outputs from the four phases of the stepper motor are each full-wave rectified, and fed to capacitor C1. Assuming that a smaller six volt stepper motor is used (e.g., from a modern scanner), each phase will produce up to 10 mA output with a brisk wind, which means that all four phases together would produce about 30-40 mA.

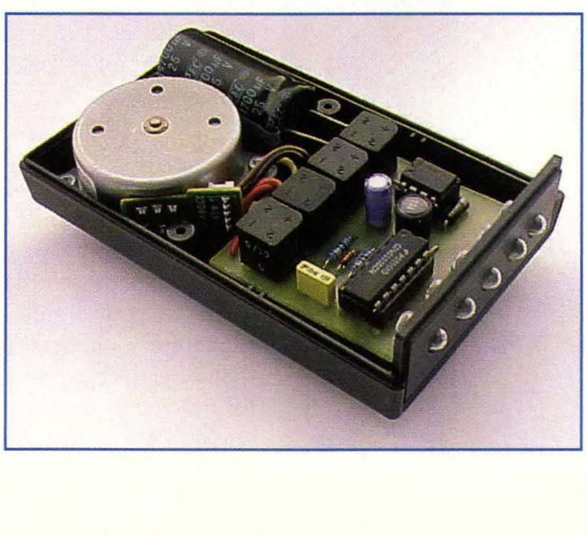
Since the present circuit draws around 7.5 mA, it could potentially support (with additional 40106 Schmitt hex inverter gates) up to 20 white LEDs off a small motor. However, winding might then need to be very brisk, and there might be no room left for pause.

C1 could be increased to, say, 20,000 µF, and the flashlight would then provide slightly extended use between winds (perhaps 10 seconds).

If a larger "power plant" was used, two small value "Goldcaps" (e.g., 2 x 0.22F in series) could be wired in parallel with C1 as shown in Figure 2, with the addition of a Zener diode and red LED for over-voltage protection as shown (the red LED indicates full charge). C1 should not, in this case, be removed. Since "Goldcaps" have a far higher internal resistance, C1 is still needed to "dump" its charge into them.

I chose the MAX639 five volt switching regulator to provide a regulated voltage for the white LEDs. In the present circuit, the regulation of this IC is not perfect, but it serves its purpose well, and is a very efficient device. It also has a low component count, which made it possible to design a particularly compact printed circuit board. It will handle input voltages between 4 and 11.5 volts, and up to 225 mA current (that is, up to 150 pulsed white LEDs if a truly powerful stepper motor is used)!

In most cases, the voltage produced across C1 should remain well within 11.5 volts. If in doubt (particularly if a larger power plant is used), test the voltage across C1. With a brisk wind, the voltage should not rise above about 10 volts — otherwise a 10 volt, 1 watt Zener diode should be wired across C1 (the cathode is wired to C1's positive terminal).



The Circuit

The schematic for this clever device is shown in Figure 1. In order to conserve power, LED1 to LED5 are pulsed with a 33% duty cycle, while the supply voltage is raised to five volts — that is, 1.4 volts above the LED's rated voltage. LEDs will happily endure a higher supply voltage on condition that they are pulsed. In fact, my white LEDs endured sustained testing at 10 volts!

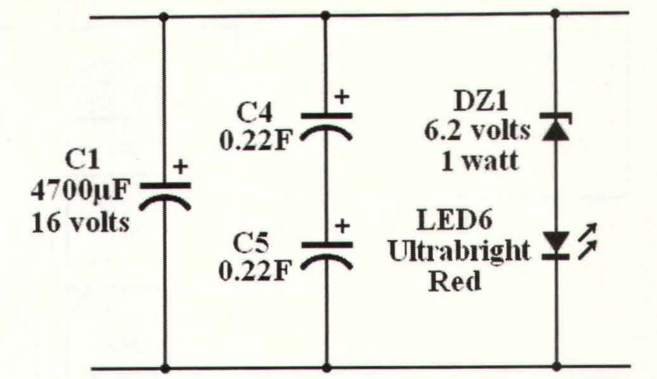


Figure 2. Optional improvements to the circuit.

You might ask why the circuit could not be run at the LED's rated voltage — namely 3.6 volts — without pulsing. On the face of it, this would seem to make for a simpler circuit and a brighter light.

However, in practice this does not work, while the 33% duty cycle of the present circuit leads to a considerable power saving (about 40 mW versus 350 mW — or nearly 90% saving).

Due to persistence of vision, the eye "sees" pulsed light for much longer than its actual duration. This may be witnessed by looking briefly into a light-bulb, then looking away at a blank wall. The image of the light-bulb will persist. Also, if current drain is reduced, C1 retains its charge longer, even if the voltage is raised by 30 or 40 percent.

Minimal power is dissipated in U2, since this introduces only a slight voltage drop across the LEDs — and it has a very small power requirement itself. I would recommend the CD40106BCN IC — other makes might introduce some flicker to the light, which would necessitate decreasing the value of C3.

R1, R2, and C3 are the timing elements of a low power "clock generator" which pulses LED1 to LED5, and these components are chosen so as to give the maximum perceived light output with minimum power consumption. The value of C is small, and that of R high, so as to conserve power.

The duty cycle of the LEDs may be changed so as to produce more light by reversing diode D1 — however, winding could then become a chore, especially if a

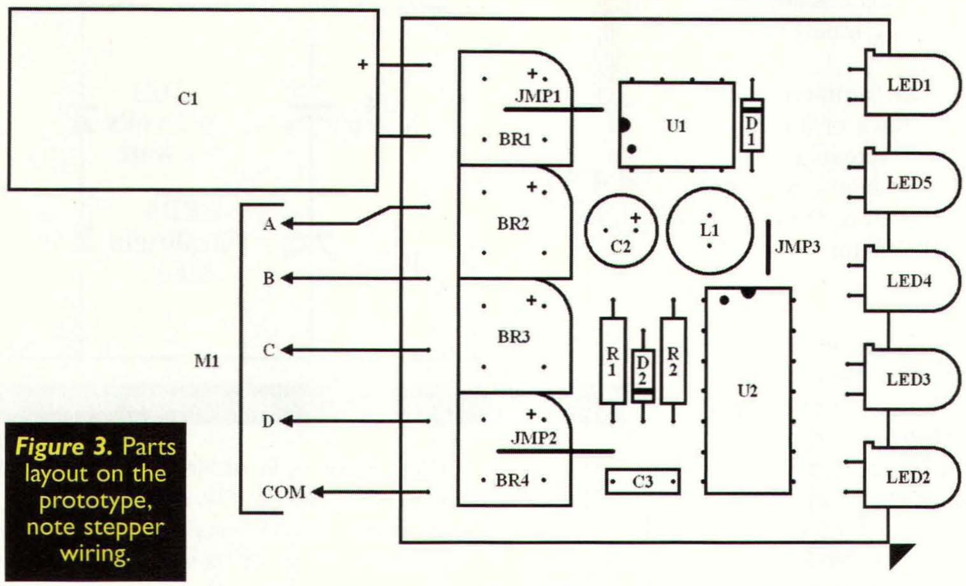


Figure 3. Parts layout on the prototype, note stepper wiring.

Wind-Up Flashlight Components

Resistors	
R1, R2	1M
Capacitors	
C1	4700 µF 16 volts
C2	22 µF 10 volts
C3	10 nF
Semiconductors	
BR1 - BR4	1A bridge rectifiers (0.2" pin spacing)
D1	1N5817 Schottky
D2	1N4148
LED1 - LED5	White LEDs, narrow viewing angle
U1	MAX639 switching regulator
U2	CD40106BCN hex Schmitt inverter
Inductors	
L1	100 µH radial inductor
M1	6-20 volt unipolar stepper motor
Optional components (see text)	
C4, C5	0.22 F (or as required) memory backup
LED6	Ultrabright red LED
DZ1	6.2 volt Zener, 1 W
U3	LP2950CZ-5.0 linear micropower regulator

Miscellaneous

2" x 2" copper-clad board, ABS plastic enclosure with end panel (the prototype's internal dimensions were approx. 3 1/2" x 2 1/4" x 3/4"), 14-pin DIP socket, 8-pin DIP socket, jump wires, nuts and bolts for M1, solder, etc.

smaller stepper motor is used. The white LEDs should have a narrow viewing angle (20 degrees or less), otherwise the beam will be too diffuse, and brightness will suffer.

Construction

A few components require special handling — namely U2 and LED1-LED5 — which are all static-sensitive. Discharge your body to earth before handling. All components should be of a high grade, since loss of power through low-grade components could lead to a less efficient flashlight.

The wind-up flashlight prototype was built on a PCB measuring 2" x 2" (see Figure 3). The internal dimensions of the original case were approx. 3 1/2" x 2 1/4" x 3/4" — however, this will only accommodate the smallest unipolar stepper motors.

Begin by soldering the two dual-in-line pin (DIP) sockets. Solder the three jump wires, the bridge rectifiers, the resistors, choke L1, then the diodes and capacitors. Capacitor C1 was kept off-board, since this is a bulky item, and some flexibility in mounting might be required.

Mark and drill five holes in the case's end panel for white LED1 to LED5. Keep their legs as long as is required for mounting in the case. The "flats" on the plastic bodies are the cathodes. The end panel in the prototype makes it possible to slide the PCB into place, which makes for easy installation.

The stepper motor is then wired up, with only the location of the common leads being critical (see Figure 3). The remaining leads may be inserted in any of the other four holes provided. Integrated circuits U1 and U2 are then inserted in their corresponding DIP sockets. The PCB may be secured with some glue, or with a layer of foam rubber inside the case to hold it tight. Finally, drill holes for the stepper motor's shaft and mounting holes, and bolt it to the case.

In Use

Briskly wind the flashlight, and the white LEDs should illuminate immediately. Do not look directly into the white LEDs, since these are extremely bright, and may represent a risk to your sight. The flashlight will need continuous, moderate winding. It may be wound in both directions — that is, clockwise and counterclockwise. (See the side-bar for modifying the flashlight's characteristics).

If there should be a risk of dampness, or if there should be the risk of the flashlight being exposed to severe weather, you might wish to solder U1 and U2 directly to the PCB, and coat the PCB with epoxy resin — taking care not to let the resin seep into the motor.

The resultant flashlight is a very durable device, which will always be at the ready — and it certainly beats striking a match! In fact it's quite serviceable around a camp table — or even for walks on a footpath at night, lighting up the way a good few yards in front.

The author may be contacted via Email with any questions thorough **scarboro@iafrica.com** NV

Further Suggestions for the Wind-Up Flashlight

Use ultra-bright yellow (or other color) LEDs to save on cost. With the circuit's 33% duty-cycle, the use of ballast resistors should not be necessary.

Replace switching regulator U1 with a 5V micropower linear regulator to save on cost. This will, however, not be as efficient as the switching regulator.

Use magnifying lenses (e.g., 10X magnification), or a Fresnel lens, to focus the beam. This gathers the light, and can greatly increase the brightness of the beam.

Employ a further 40106 hex Schmitt inverter IC, and wire up more white LEDs for increased brightness (however, winding is likely to become more demanding).

Wire a six to nine volt battery and an on-off switch across C1 (the battery positive is wired to C1's positive terminal). In this, way the battery powers the flashlight, and winding is only required if the battery is dead.

Increase the value of C1 to about 20,000 μF for extended use between winds.

Employ "goldcaps" as described in the text, for greatly extended periods of use. In this case, a larger and more powerful stepper motor is recommended.

Try other types of motor — e.g., synchronous motors or bipolar stepper motors. Keep a check on charge across C1, which should not rise higher than about 10 volts — otherwise the Zener diode arrangement of Figure 2 should be used. DC motors are unlikely to work.

To use the flashlight as a book-light, reduce the number of LEDs to one, and employ the "Goldcaps" as described. A more powerful stepper motor is again recommended.

by Thomas Henry

Snap, Clank, Clatter!

Give Neil Peart a Run With this Metallic Sound Synth

3D modeling by Dennis San Vicente

The earliest electronic music synthesizers were keyboard-based instruments, played not unlike an organ. Shortly thereafter, clever designers started applying synthesis techniques to drums and percussion. This has revolutionized the music industry and many drummers today augment their set-ups with electronic equivalents, or even forego traditional trap kits altogether in favor of synthesized percussion. Adding to the versatility, electronic drums can be easily put under computer control thanks to the popular MIDI interface. And all this is available to the experimenter, especially since *Nuts & Volts* magazine has presented a number of construction articles over the years explaining how to build pro-quality instruments from scratch.

But one notable instrument has been missing from the DIY arena ... until now. The cymbal and its relatives (collectively referred to as clangorous instruments) have not been part of most homebrew music systems. The reason for this is that clangorous and metallic sounds are among the most difficult to synthesize realistically, and many experimenters

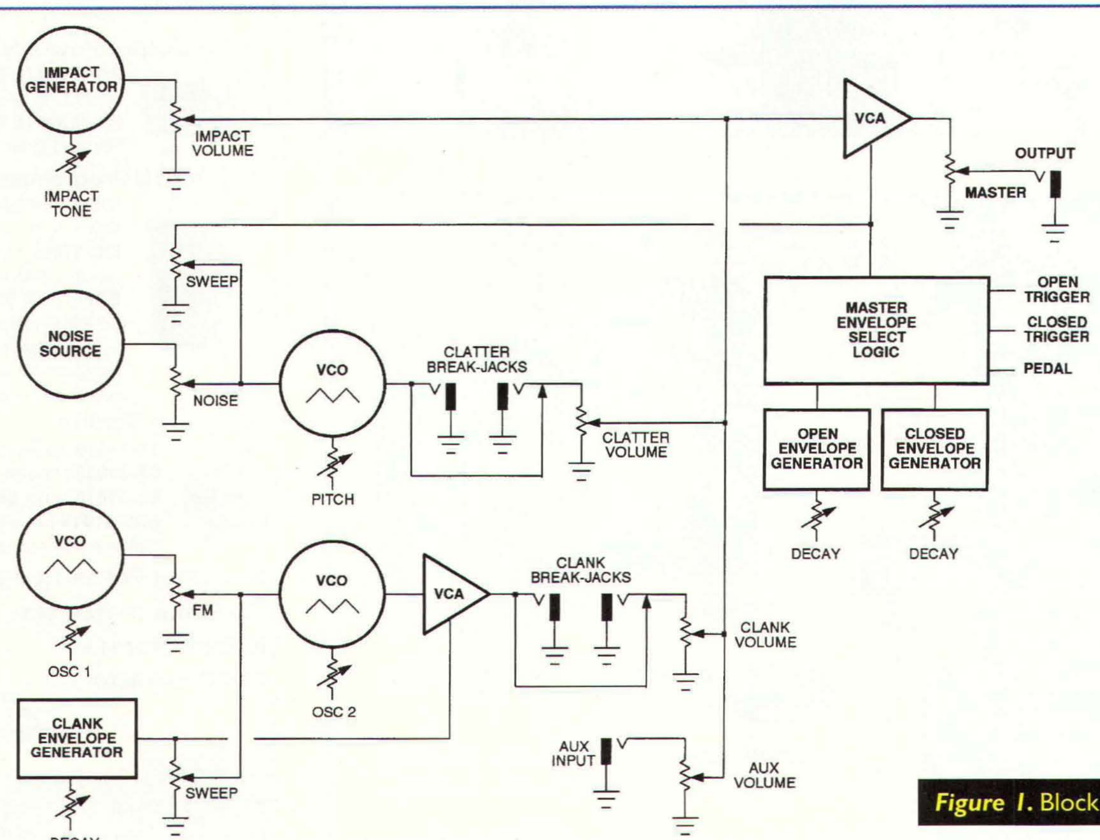


Figure 1. Block Diagram

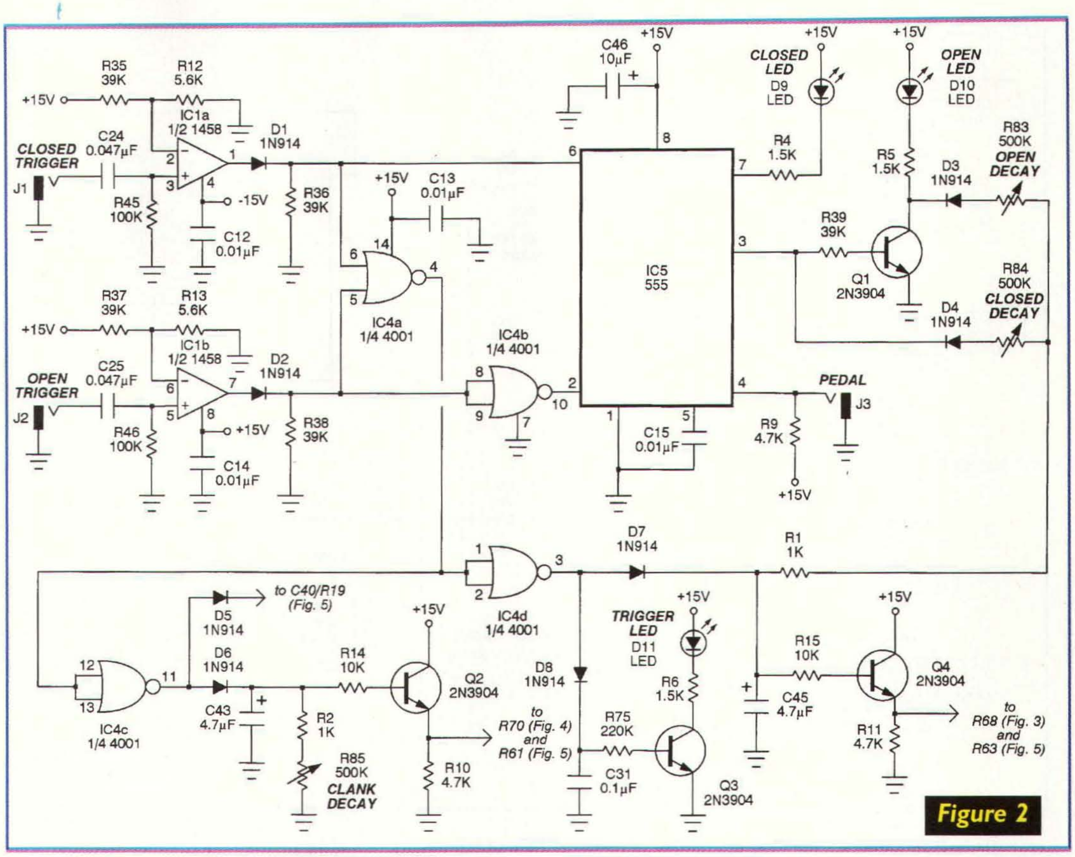


Figure 2

hardly know where to begin. Bass drums, tom-toms, and even snare drums are fairly straightforward to mimic, since the easily-synthesized damped sine wave is at their heart. But metallic sounds like chimes, cymbals, cowbells, and the like are another matter altogether.

Enter the Clangora! This is a full-featured electronic hi-hat circuit with no commercial equivalent. It's not boasted that it will exactly duplicate the standard hi-hat, but Clangora does suggest the sound more closely than any other analog circuit you're apt to meet. And besides, the Clangora is capable of a wide variety of other metallic sounds. Yes it's a big circuit, but as you'll see, the individual modules comprising it are fairly simple to understand if you consider them one-by-one. Despite its apparent complexity, there is nothing particularly critical about the circuit, putting it within reach of the average weekend project builder. Let's jump right in and see how it works before turning our attention to construction details.

Understanding Clangora's Modules

A cymbal sound consists of at least three main sonic components. First, there is the initial snap of the stick striking a surface. This is called the impact tone and is quite short and sharp. Immediately after this follows a metallic clank, which might hang on considerably longer depending on the mass of the cymbal and how it is supported. Finally, in the case of a hi-hat, there are actually two platters abutting one another loosely and their interaction creates what can be called the clatter. Altogether, a lot goes on when you smack a cymbal! And yet, with a bit of ingenuity, it is possible to imitate these components electronically.

Refer to Figure 1, which shows a block diagram for Clangora. You will notice that there are three major audio components: the impact, clank, and clatter generators. The impact generator sports two controls — one to set the overall volume and one to adjust the tone for bass or treble response.

Next, the clank effect is produced by allowing one voltage controlled oscillator (VCO) to modulate the frequency of another — called FM. This is a great way to generate metallic sounds. There are controls on the VCOs which permit you to set the initial frequency of each. Another knob lets you dial in the amount of frequency modulation desired, greatly extending the range of possible sounds from realistic to outer-spacey. But even with this, things could be a bit static, so we also sweep the second oscillator in response to an envelope generator. Thus, the harmonic content of the clank changes with respect to time, which is exactly what happens in a real cymbal for various physical reasons. Notice that both the frequency and amplitude of the clank section are modulated by an envelope generator. A separate voltage controlled amplifier (VCA) imposes an amplitude pattern on the clank sound. This is important, since the clank dies out more quickly than the clatter which lingers on as the cymbal gradually dissipates energy.

A pair of jacks — called break-jacks — lets you tap into the clank sound if desired, and insert an additional processor like an audio equalizer, reverb, or ring modulator. This really opens things up for tweaking the sound.

The clatter section begins with a rather exotic noise source. This isn't your usual white noise generator, but in fact, it creates a dissonant mixed-tone effect. And rather than employing the output directly, we force it to control yet another VCO. This yields a tunable noise source which can be dialed up and down across the entire audio band.

Other controls contribute to the fantastic versatility here. The basic pitch of the noise can be set, as mentioned above, but can also be swept in response to the master envelope

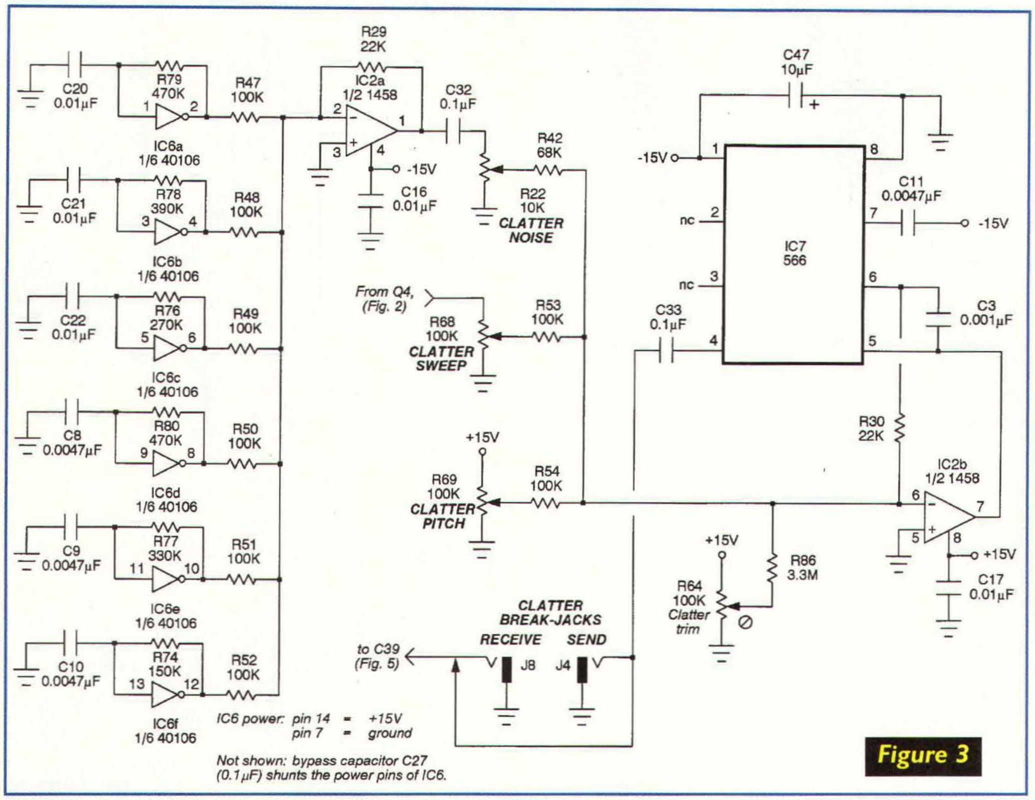


Figure 3

generator. Again, a cymbal sound is anything but static, and by sweeping the clatter over time you get a much more realistic filtering effect. Another set of break-jacks allows you to inject further processing here, as well. There's even an auxiliary input in case you'd like to patch in some other synthesizer circuit.

The impact, clank, and clatter tones are all summed at the master VCA. This VCA changes its gain in response to an envelope generator. The attack time is fixed to be as fast as possible, since that's the way most percussion behaves, but the decay is adjustable and can die out over a period of several seconds. A real hi-hat is controlled by a foot-pedal which opens and closes the platters — the decay of the open pair, of course, is much longer than that of a pair snapped up against each other. So, the VCA is managed by two independent envelope generators.

There are separate trigger jacks for these letting you control both aspects of Clangora by computer. And for real-time percussionists using electronic drum pads, there's even a pedal input which lets you "open and close" the cymbals with an SPST footswitch. With this overview of the modules under our belts, let's dig deeper into the electronics and see how the circuit actually works its magic.

How the Circuit Works

Much of the action in Clangora centers around the envelope generators, so let's start with them first. Refer to Figure 2. The master VCA is controlled by one of two envelopes chosen by the envelope select logic — recall that a hi-hat has both an "open" and a "closed" sound depending upon how tightly the platters are pulled into contact with each other. Jacks Jl and J2 send open and closed triggers to the unit. To ensure that Clangora is compatible with as wide a range of musical gear as possible, op-amps IC1a, IC1b, and their associated components clean up the input triggers considerably. Let's trace the closed trigger as our example, bearing in mind that the open trigger works the same way.

C24 differentiates an incoming pulse and applies it to comparator IC1a. The threshold of the comparator is set at about 1.8V by means of divider R35/R12. The output will snap cleanly when any trigger exceeding this value comes in, and diode D1 ensures that the swing is only positive.

The squared-up triggers are then fed to the logic circuitry consisting of the NOR gates and IC5 — the 555 chip. Now, before you think you've seen this all before, you might want to note that IC5 is not being used as a timer! In this configuration, it is set up as high power R-S flip-flop. Pin 2 is the set input while pin 6 provides the reset function. Pin 3 is the output. Depending on the state of the output, either D3 or D4 — but not both — is pulled to ground, thus providing a discharge path for C45 (the main envelope generator timing capacitor) through either the open decay control or the closed decay control. Pulling this all together then, an open or closed trigger either sets or resets the R-S flip-flop, and its output selects one of two possible discharge paths.

By the way, it should be obvious that the attack is fixed, and is created by dumping a charge onto the timing capacitor, C45, via diode D7. Notice that D7 passes current when either the open or closed triggers occur. That's because NOR gate IC4a is followed immediately by the inverter IC4d. You get a NOT-NOR out of the deal, which is nothing more than the simple OR operation. The timing capacitor is charged rapidly giving a near instantaneous attack — it's the decay that is adjustable by either R83 or R84.

Pin 4 of the 555 acts as a master reset control. It will override whatever the chip is currently doing and pull the output to ground, thus closing the hi-hat. An ordinary SPST footswitch can be plugged into jack J3 for pedal control. By the way, two LEDs give an indication of which decay control is currently selected. D10 lights when the open decay control is in effect, while D9 indicates that the closed control is engaged. And in case you're wondering why an off-the-shelf flip-flop wasn't used, consider that it has to sink a substantial amount of current in this application. The 555 shines in this respect, and at the same time, provides all of the niceties, like a master reset (pin 4) and an auxiliary output (pin 7) for the LED. As mentioned above, the currently selected envelope voltage is developed across C45, and the emitter follower made up of Q4 and associated components buffers the signal. Q3, along with D8 and C31, acts as a pulse stretcher and makes sure that the trigger indicator light D11 shines long enough for the human eye to detect.

The clank circuitry requires its own independent envelope generator. A straightforward one comprising D6, R2, R85, and C43 creates the desired envelope that's buffered by Q2. All in all, it's a very simple affair, but does work quite well.

That pretty much covers the envelope generator stuff, so let's move on to the clatter circuitry. Refer to Figure 3 now. Six separate Schmidt trigger oscillators form the main noise-making bank. You might not have seen this approach before. These oscillators were tuned empirically, right at the workbench, to create a deliberately dissonant effect. The sound is quite weird and already begins to seem metallic in nature. The six outputs are summed by mixer IC2a, and then coupled to the clatter noise depth control R22. But rather than tapping this as an audio output, let's continue by using the signal to modulate a VCO. This is a sweet way to make the noise source tunable over the entire audio spectrum, yielding deep bass rumbles on up to brittle treble screams.

The noise output is used to modulate the frequency of a 566 VCO chip and associated components. Like the 555 we saw earlier, this is a very non-standard configuration which may be new to you. For starters, notice how the chip is powered. Usually pin 1 is grounded, and +15V is applied to pin 8. But in this situation, we put pin 1 at -15V and pin 8 at ground. Don't let this strangeness worry you — as far as the 566 is concerned, there's still a positive 15V potential straddling its supply pins. The reason for taking this odd approach is that we can now do clever things to obtain a much wider and predictable response. The details of how it works are beyond the scope of this article, so let's just note that the internal current source of the 566 (accessed via pins 5 and 6) is placed within the feedback loop of op-amp IC2b. This has the effect of forcing the control voltage to be referenced to ground, and also offers up a response which covers the entire audio range of around a dozen octaves. (The span of the 566 is normally limited to a piffling several octaves).

IC2b sums the voltages that control the VCO's output frequency. As mentioned earlier, the noise output is applied via potentiometer R22. A center frequency or pitch is set via a fixed voltage supplied by control R69. And the clatter envelope generator can sweep the frequency of the noise source dynamically, thanks to the input applied to pot R68. All in all, you get a tremendous amount of control over the sonic qualities of the clatter here. Incidentally, trimmer R64 ensures that the lowest points on the dials still produce a legitimate sound.

Finally, notice that the clatter output is AC coupled from pin 4 through C33 before passing on to the break-jacks mentioned earlier. Use these to insert additional processing if desired; otherwise, the signal simply moves on to the master VCA, yet to come.

Now turn your attention to the clank section in Figure 4. As described above, two VCOs are pressed into service here, one modulating the frequency of the other. IC8 is the controlling oscillator — this 566 chip being configured in the standard way, since we don't need much range here. C26 and R23/R3 provide the main timing elements. The usual FM input at pin 5 is simply biased up to a convenient point to ensure the 566 oscillates across the entire range of R23's span. The output is a triangle wave, found at pin 4.

The second oscillator, IC9, is configured like that in the

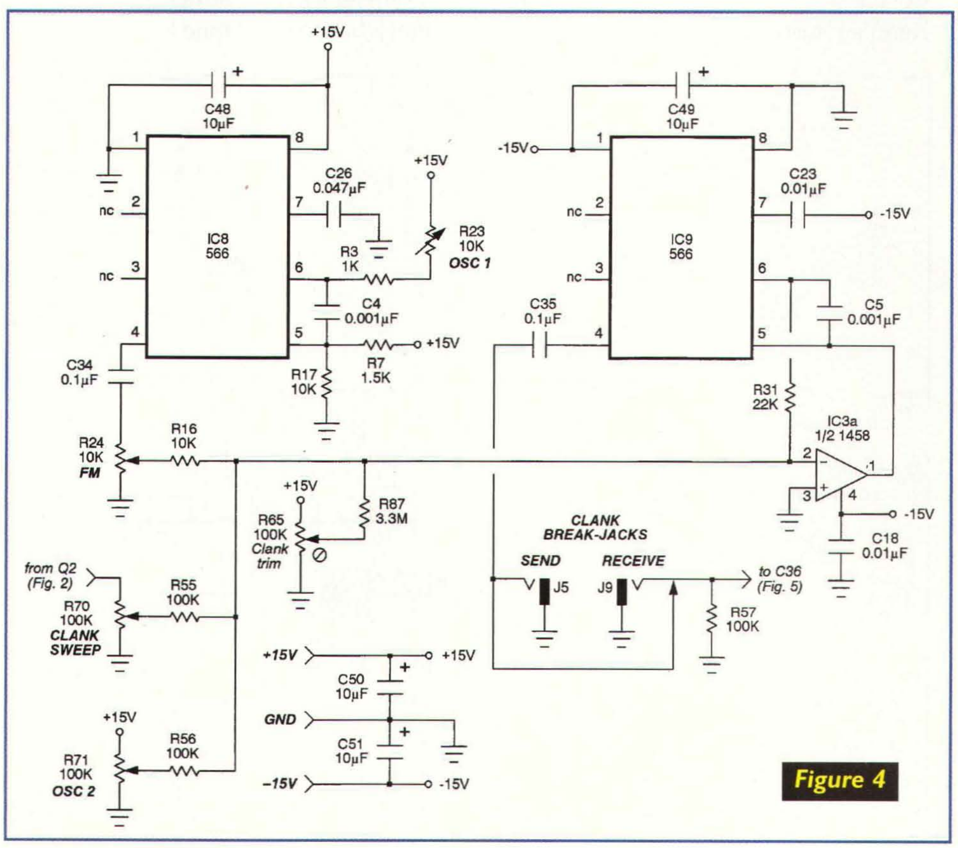
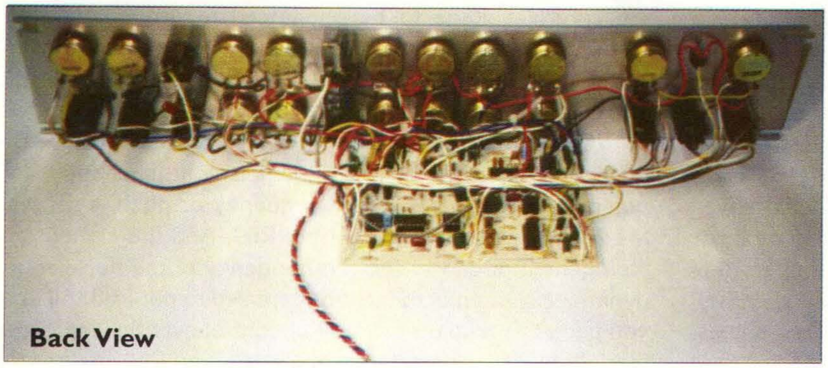


Figure 4



Back View

clatter section. IC8 modulates it under control of potentiometer R24. The basic operating frequency is set by pot R71. Finally, R70 applies a voltage tapped off of the clank envelope generator described back in Figure 2. These three control signals are summed by op-amp IC3a and then applied to the 566. The frequency modulated triangle wave coming out at pin 4 sounds uncannily like the ringing of metal — once we impose an amplitude envelope on it we'll have cymbals, cowbells, and other clangorous effects at our fingertips.

Look back quickly at Figure 2. Note again that IC4a is a NOR gate, but that this is followed immediately by inverter IC4c. Thus, the output passed on by diode D5 will snap to attention if either an open or a closed trigger occurs. Now move on to Figure 5 to see how this is used to fire the impact generator. The pulse is applied to a simple tone control consisting of C40/R8, C41/R19, and potentiometer R25. Here we have a simple circuit, but it gets the job done. Throw in control R27 and you now have the power to adjust both the volume and tone of the impact effect.

So, we've got all the sounds we need and we have the various envelopes. The time has come to pull them all together and route the signals to the VCAs. IC10, which is the amazing NE570 compander chip, is pressed into service (again in a slightly unconventional manner) to act as a dual VCA. Let's follow the path of the clank generator which was described earlier. This is applied to pin 3 of the 570 after suitable scaling and coupling by R18 and C36, respectively. Trimmer R66 lets you compensate for any DC offsets at the gain cell input, reducing undesirable "thumps." (This may seem strange in a drum circuit, but the only thumps we want are those we create on purpose!)

The usual rectifier circuit is disabled by bypassing pin 2 to ground via C28. Instead, we inject a VCA control voltage at pin 1, after it's restricted appropriately by resistor R61. If you trace this back to Figure 2, you'll discover that the control voltage comes from the clank envelope generator. Recall that the attack time is very short, so the VCA opens up almost instantaneously, yielding full volume. But then as the timing capacitor discharges through decay pot R85, the amplitude dies away slowly. The effect is that we've imposed an amplitude envelope onto the basic clank generator, and even with just this much it's beginning to sound like you struck a piece of metal and made it vibrate for a while. The tone eventually dies away.

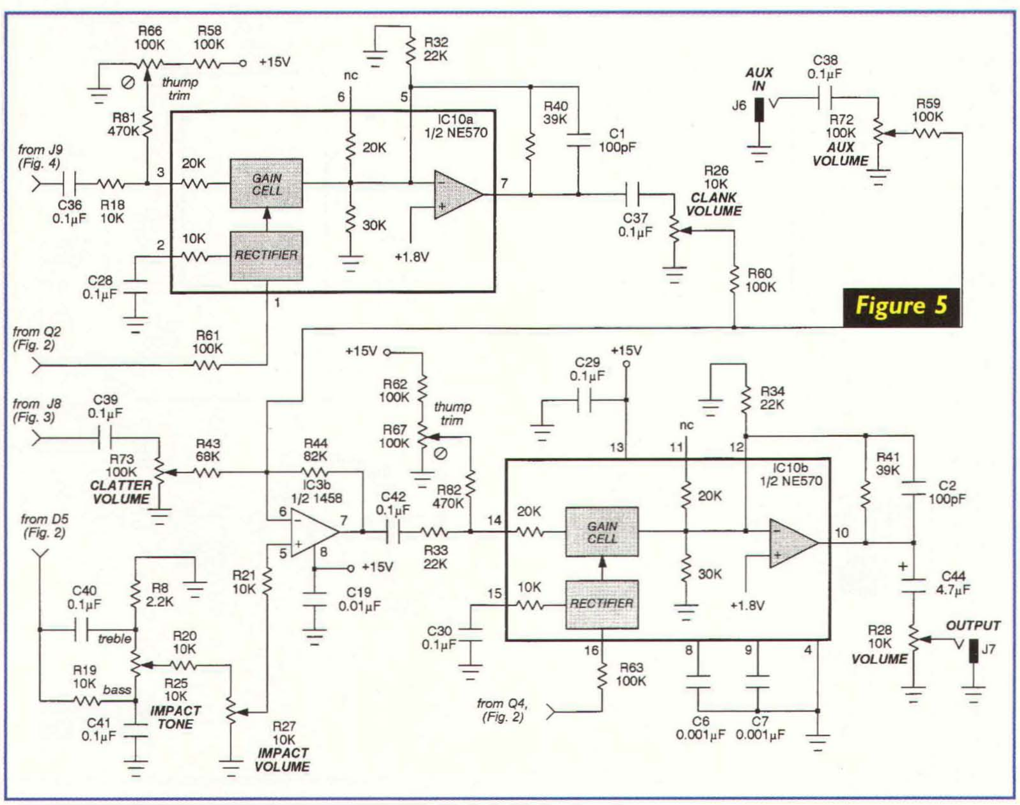


Figure 5

But to finish up the VCA, the gain cell output is sent to an op-amp internal to the NE570 whose gain is set by R32 and R40. C1 limits the supersonic high end, just to nail any RF garbage in its tracks. Potentiometer R26 is the master clank volume control, and then the signal is routed to the remaining VCA.

The second half of the NE570 compander chip is configured in an identical fashion to create a master VCA. Notice that the various audio inputs (clank, clatter, and impact tone) are summed first by mixer IC3b and then applied to the voltage controlled amplifier. The mixed output is tamed by volume control R28.

One final detail — on all of the figures, you might have noticed some capacitors that weren't mentioned. Most of these are bypass or decoupling caps. These should be attached as closely as possible to the power supply pins of the various chips. Their purpose is to prevent undesirable interaction as any garbage attempts to hitch a ride down the power supply rails. These capacitors are important to pro-quality sound equipment, so don't skimp on them.

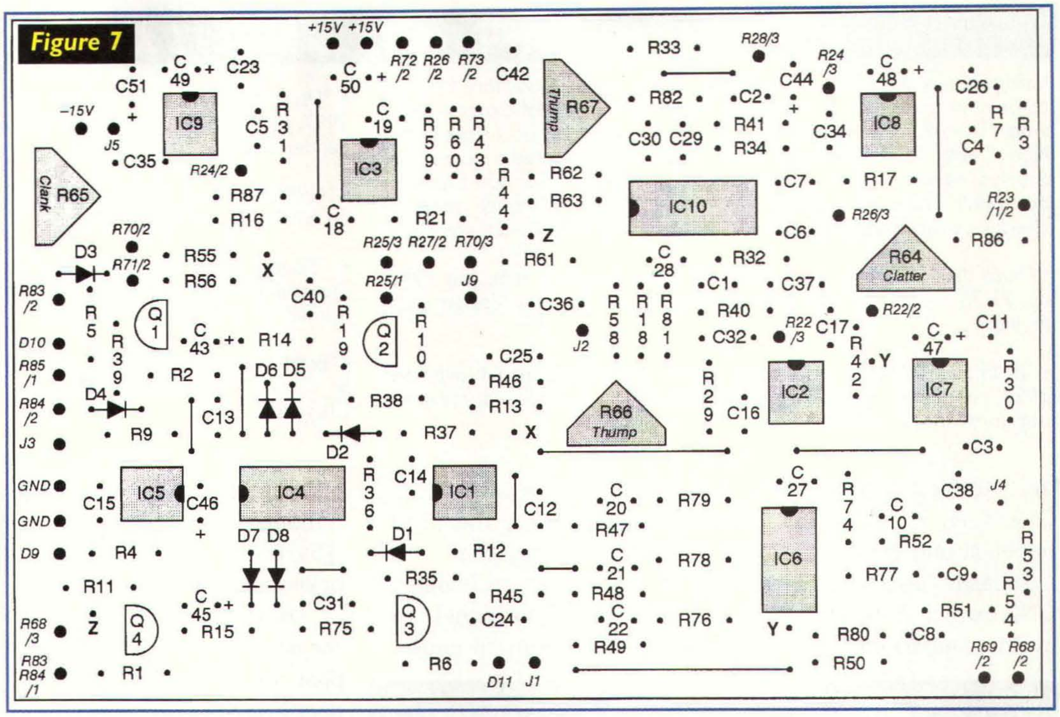


Figure 7

Let's Build It!

Your first step is to gather together all of the components; refer to the Parts List. There's a lot of them, but fortunately most are pretty easy to find. The NE570, which was an extremely popular chip 20 years ago, is perhaps a little harder to locate nowadays. However, as a service to readers, arrangements have been made so that you can obtain it by mail order especially for this project. See the Parts List for details.

There's nothing especially critical about the Clangora, so it could be wired by hand as long as you are patient and neat about it. But since it's a large circuit, perhaps the easiest way to go is by means of a PCB. Figure 6 shows the lifesize artwork, and can be seen on the *Nuts & Volts* website (**www.nutsvolts.com**). You can find suppliers for most of these circuit board production items in the advertisements within *Nuts & Volts* magazine.

Figure 7 shows the parts placement guide. The orientation of the components should be obvious, but be sure to double-check your work as you go along. In particular, make certain you get the polarities of the electrolytics right, and watch the positioning of the transistors and diodes. Finally, note that there are 14 jumpers on the board (the price for not going with a double-sided PCB!). You can use leftover snippets of component leads, or short pieces of bare buss wire for most of these. However, note that three connections must be made with insulated wires. These join the individual pairs of pads labeled X, Y, and Z, respectively.

Now's the time to start working on the front panel and enclosure. To make the Clangora compatible with other studio rack-mounted gear, a standard 2U panel is perhaps best. This has the dimensions of 3-1/2 inches by 19 inches, and is usually made of 1/8 inch aluminum stock. Figure 8 shows a suggested layout. After marking and drilling all holes, consider using a computer art program with decal transfer sheets to label everything. Several coats of clear plastic paint will protect the panel from most abuse. By the way, you can use tiny angle brackets and #4 hardware to secure the PCB board behind the front panel.

To complete the wiring, refer back to Figure 7. You will notice that the connections to the various pots, jacks, LEDs, and so forth are clearly indicated with italic lettering. For example, a designation of R69/2 means that you are to wire this pad to the second (middle) lug of potentiometer R69 —

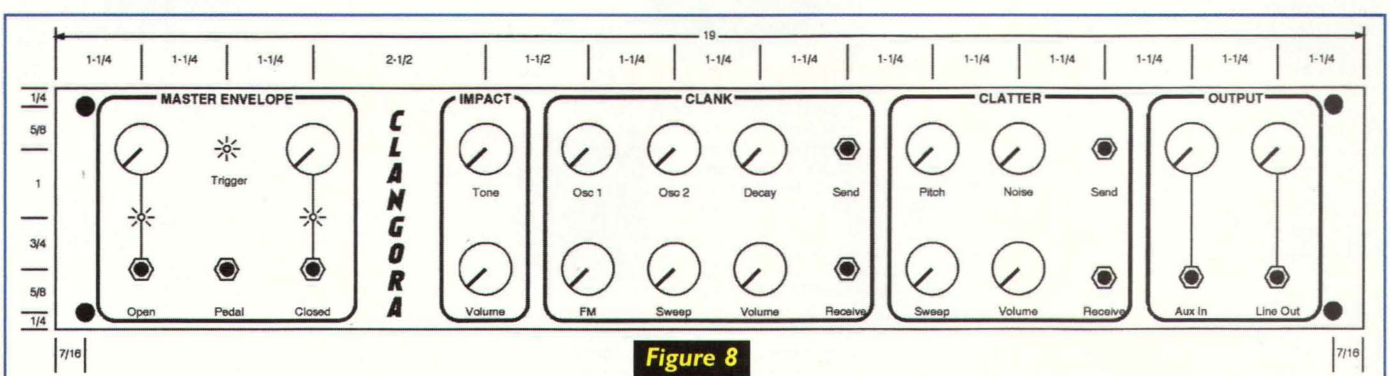


Figure 8

BUILDING IT? — *NUTS & VOLTS* CAN HELP!

Clangora is a big circuit, so necessarily the description here has had to be short and to the point. But if you're the type of experimenter who clamors for more details, then you need look no further than *Nuts & Volts*. Over the years, *Nuts & Volts* has published a number of articles which directly influenced the implementation of Clangora here. Pull these issues down from your home reference shelf, or check out the availability of back issues on the *Nuts & Volts* website.

- *"Build the ADV-Snare,"* by Thomas Henry and Jack Orman, July 1996, pp. 71-75 — lots of info on essential electronic drum design techniques
- *"Build the ADV-Bass,"* by Thomas Henry and Jack Orman, November 1996, pp. 56-59 — the simplest electronic drum to build, great for beginners in drum synthesis
- *"User's Guide to Special Audio Processing ICs,"* by Ray Marston, May 1997, pp. 55-59 — details on the inner workings of the NE570 compander chip used in Clangora
- *"Add MIDI to Your Electronic Drums,"* by Thomas Henry, October 1997, pp. 62-67 — the title says it all
- *"Secrets of Making Attractive Rack Panels,"* by Thomas Henry, December 1998, pp. 72-75 — the ins and outs of designing beautiful homebrew rack mount equipment
- *"Build a Tunable Noise Generator,"* by Thomas Henry, November 1999, pp. 25-27 — explains how noise can modulate a VCO, as used in Clangora

the clatter pitch control. Also, observe that some parts (C38, C39, C41, R8, and R57) mount directly behind the front panel, strung between various potentiometers or jacks.

Lastly, note that there is an extra ground pad (labeled GND) which is used to bring ground to the front panel. To avoid ground loops and the insidious hum they can cause, ground should tie to the front panel at one point only. The remaining GND pad is employed, along with the +15V and -15V pads, to provide connection to your regulated bipolar power supply.

After you've double-checked all of your work, it's time to fire up Clangora and adjust the trimmer pots. Assuming you pass the smoke test with flying colors, patch a source of triggers into the open and closed jacks, and connect the audio output to an amplifier and speakers. Watch the volume control until you get used to what's emanating, just to avoid bruising either your equipment or your ears. While triggering the unit repeatedly, adjust the two trimmers (R66 and R67) to minimize any undesirable thumping in the VCAs. Next, tweak trimmers R64 and R65 to set the sweep range for the clatter and clank, respectively. You want to attain the largest sweep range possible, avoiding any dead spots where the VCOs might stall.

And that's it! Now comes the big (but fun) job ... learning the controls. Whatever you do, be patient. Like with any fine musical instrument, it is possible to create some angelic

Resources

As a special service to readers, a set of one NE570 and three 566 VCO chips is available for $25.00 from Midwest Analog Products. This price includes shipping by first class mail anywhere in the US. Minnesota residents please add 6.5% sales tax. Readers from other countries please inquire first for exact shipping charges.

Order from: Midwest Analog Products
P.O. Box 2101
N. Mankato, MN 56003
Email: contact@midwest-analog.com
Web: www.midwest-analog.com

PARTS LIST

All resistors are 1/4 watt, 5% values.

R1 - R3	1K
R4 - R7	1.5K
R8	2.2K
R9 - R11	4.7K
R12, R13	5.6K
R14 - R21	10K
R22 - R25	10K linear taper
R26 - R28	10K audio taper
R29 - R34	22K
R35 - R41	39K
R42, R43	68K
R44	82K
R45 - R63	100K
R64 - R67	100K trimmer taper
R68 - R71	100K linear taper
R72, R73	100K audio taper
R74	150K
R75	220K
R76	270K
R77	330K
R78	390K
R79 - R82	470K
R83 - R85	500K linear taper
R86, R87	3.3M

All capacitors are 16V or better.

C1, C2	100pF disc
C3 - C7	0.001µF mylar
C8 - C11	0.0047µF mylar
C12 - C19	0.01µF disc
C20 - C23	0.01µF mylar
C24 - C26	0.047µF mylar
C27 - C30	0.1µF disc
C31 - C42	0.1µF mylar
C43 - C45	4.7µF electrolytic
C46 - C51	10µF electrolytic

Semiconductors

D1 - D8	1N914 or 1N4148
D9 - D11	red LED
Q1 - Q4	2N3904 NPN
IC1 - IC3	1458 dual op-amp
IC4	4001 CMOS NOR gate
IC5	555 timer
IC6	40106 CMOS Schmidt trigger
IC7 - IC9	566 VCO
IC10	NE570 compander

Other components

J1 - J7	1/4" phone jack, NO
J8, J9	1/4" phone jack, NC

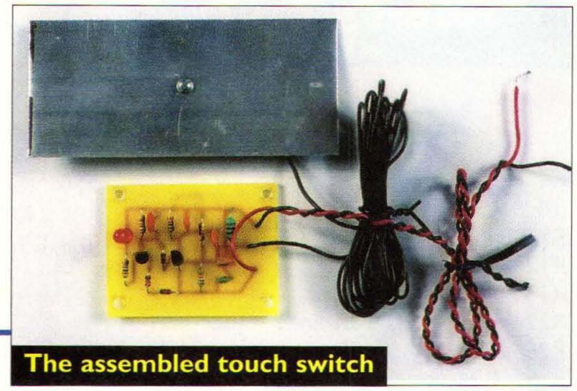
Miscellaneous: printed circuit board, LED holders, IC sockets, front panel, knobs, wire, etc.

sounds and some extremely ugly ones. So you'll want to put in a fair amount of time experimenting to discover exactly what the effect is for each control and which settings work well together. But if you give it the rehearsal time it deserves, you should come away mastering one of the most versatile electronic drum circuits ever. **NV**

by Paul Florian

Add A Touch Of Control

Learn About Tank Circuits With This Simple Project



The assembled touch switch

The circuit in Figure 1 is the schematic of a touch switch of rather simple design. When your finger is in contact with the touch plate, the LED is illuminated. When you move your finger away from the plate, the LED is turned off.

Theory of Operation

The circuit consists of an oscillator, rectifier, and threshold detector. The oscillator is composed of L1, C2, C3, and Q1. The operating frequency is given by F=1/(2 * PI * SQRT(L1 * Ct)), where Ct equals the series capacitance of C2 and C3. Ct = 110 pF. Using the equation gives an operating frequency of approximately 5 MHz. When you touch the plate with a finger, the tank circuit is loaded with your body impedance. This prevents the oscillator from working. D1, R4, and C4 rectify and filter the voltage at the emitter of Q1. Q2, D2, and D3 form a threshold detector. The threshold voltage of Q2 is set at 3 VDC by the voltage drop of the diodes D2, D3, and Veb of Q2. This is equal to the supply voltage - VD2 - VD3 - Veb. With a 5 VDC supplying, this produces a threshold voltage of (5 - 0.7 - 0.7 - 0.6) = 3.0 VDC. When the base voltage of Q2 is greater than the threshold voltage (3 V), Q2 will remain off. As stated earlier, whenever the plate is touched, the oscillator does not run and this causes the voltage at the anode of D1 to be approximately 1.6 VDC. Therefore, D1 is reverse biased and the cathode of D1 is pulled down to 3 V by R4. This turns on the LED. However, when the touch plate is not in contact with a body, D1 rectifies the 5 MHz from the oscillator. Then the signal is filtered and results in approximately 4 VDC at the base of Q2. This voltage is greater than the threshold voltage of 3 VDC, so Q2 is off and the LED does not glow.

Construction

You may download a full-size copy of the PCB from the *Nuts & Volts* website (**www.nutsvolts.com**). Note that the text on the PCB should read PCFTS03, not its mirror image. Once the circuit board has been etched and drilled, install the components listed in Table 1. Install resistors R1-R5. Next, mount diodes D1-D3, and LED D4. Then solder L1 and C1-C5 to the board. Finally, install Q1 and Q2. Be careful to note polarity and part number when installing these transistors. Q1 is a 2N3904 NPN transistor and Q2 is a 2N3906 PNP transistor. Solder a one-foot piece of red wire to the pad marked V+ and solder another similar length of black wire to the pad marked Gnd. These wires can be twisted together for a more professional appearance. The twisting can be accomplished by chucking both wires in a variable speed drill. Hold one end of the wires while the drill is on low speed. Twist until there are four to eight turns per inch.

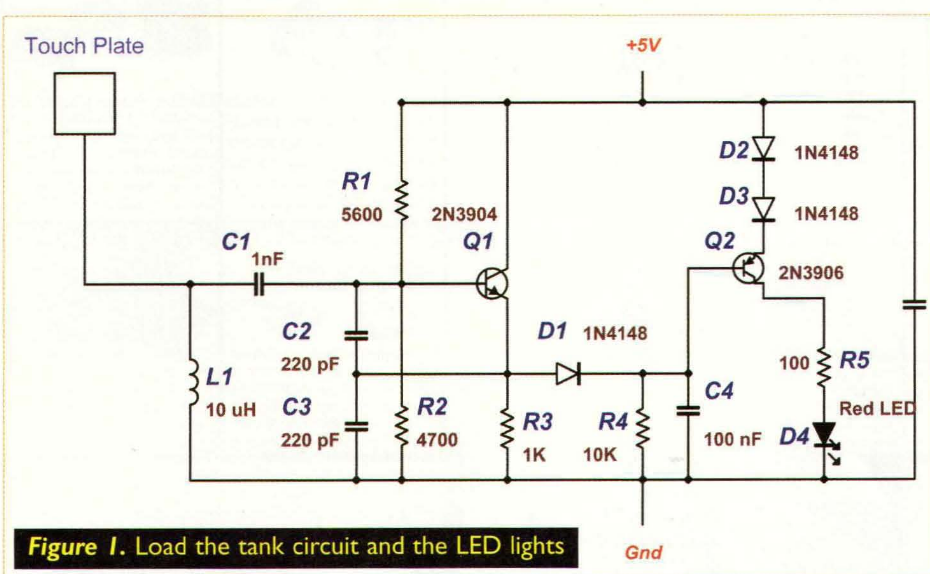


Figure 1. Load the tank circuit and the LED lights

The touch plate is constructed from a piece of 2" x 4" x 1/16th inch thick piece of metal such as aluminum, copper, tin, brass, or copper clad PCB material. The circuit design has been tested with wire lengths of up to six feet between the touch plate to the circuit board.

Testing

Once the circuit has been assembled and the touch plate wired to the PCB pad marked "Plate," check for solder shorts, cold solder joints, and correct installation of polarized components. Apply 5 VDC to the red wire and ground the black wire. Measure the voltage between the cathode of D1 and Gnd (without touching the plate) — this should be approximately 4 VDC. This means that the oscillator is running, and the LED should be off. If this is not the case, check for proper installation of L1, C2, C3, and Q1. When the plate is touched, the voltage at the emitter of Q1 to ground should read 1.6 VDC, the voltage at the cathode of D1 to Gnd should measure approximately 3 VDC, and the LED should be on. If different results are obtained, check the correct installation of D1-D3, and LED D4.

Conclusion

Feel free to experiment with different size touch plates and different lengths of wire connecting it to the circuit board. The touch switch can run off of any voltage between 5 and 12 VDC. If a voltage other than 5 VDC is used, R5 will have to be recalculated for an LED current of 10 mA, using the equation (Vsupply - Vd2 - Vd3 -Vled)/i. Solving the equation for 12 VDC supply gives R5 = (12 - 0.7 - 0.7 - 2.1)/0.01, or about 850 ohms. Use an 820 ohm resistor since it is the closest standard part value. You may also want to replace the LED with a small reed relay, taking care to limit the coil current in the same manner.

This circuit can be used as a building block for more complex designs where having a touch switch may prove useful. The touch switch is an educational as well as fun to build project. NV

Part Designation	Part Value
R1	5.6 KΩ 5%, 1/4W
R2	4.7 KΩ 5%, 1/4W
R3	1 KΩ 5%, 1/4W
R4	10 KΩ 5%, 1/4W
R5	100 Ω 5%, 1/4W
C1	1 nF ceramic disc
C2,C3	220 pF ceramic disc
C4	100 nF ceramic disc
C5	10 nF ceramic disc
L1	10 µH inductor
D1-D3	1N4148 diode
D4	Red LED
Q1	2N3904 NPN
Q2	2N3906 PNP
Plate	See text
Hookup wire	

Table 1

Tech Forum

QUESTIONS

I am using a 4017 sequencer IC to light a small Christmas display, using the first nine steps to light each element. On the tenth step, I would like all nine outputs to light up, and then repeat. I am using relays (12 volts, 700 ohm coil) to interface the IC and display. My problem is, I can't get the nine outputs to light all at once. How do I wire this?

#11031 **Sam Azzarelli**
via Internet

I need a circuit that can measure viscosity of an oil at temperatures up to 250 degrees F and under pressures of up to 200 PSI. I was thinking that a quartz crystal, with a self resonating circuit, could just measure the different frequencies, as I know temperature would affect the results. Would this work? I could submerse a motorized paddle in the oil and measure the motor current, but it would be hard to build because of the pressure, temperature, and sealing.

#11032 **Dennis Anderson**
Ontario, Canada

Does anyone know where I can find plans to build a digital refractometer?

#11033 **Dr. Bolt**
via Internet

Is the state-of-the-art in video teleconferencing good enough to conduct music lessons over a camera pair on the Internet? Is anyone currently doing this? I would like recommendations on the best buy in cameras and software, assuming that both parties have mid-grade computers and cable modems, and one user has his own web page.

#11034 **Joe Ennis**
via Internet

I would like to pick up the digital transmissions of some law enforcement agencies — such as the LAPD — like an APCO 25 decoder does. Bearcat has one available but you have to buy their scanner ($300.00 or so) and add another $300.00 for the add-on decoder board, which is not cheap.

I own AR3000 and AR8000 scanners and AOR keeps telling me that they are working on it, but as of yet ... nothing. If this is feasable with my scanners, can someone tell me where to pull the detector output from on the PCB?

#11035 **Ted Demas**
Woodland Hills, CA

I am a major audio and music buff. I would like to build a display just like the one on an audio equalizer that provides a visual display of the seven major bands.

Does anyone have a circuit that I could use to make this using LEDs? It would really add to the setup I have now with my LED VU meter.

#11036 **Shon Kelly**
Ottawa, Canada

Does anyone know of a simple data logger I can use? I want to record the time and date of each instance a switch is turned on and off, and keep it in memory.

#11037 **Joel Fleuranceau**
France

I just bought a number of Gateway 2000 4DX-66V computers at a very low price, but they have a BIOS password enabled that prevents them from booting up. Is there a master password that I can use just to get in?

#11038 **Jeanette Jernigan**
via Internet

I would like to build an ultrasonic cleaner suitable for small objects (jewelry, watch parts, etc.). Does

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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!

Send all material to *Nuts & Volts Magazine*, 430 Princeland Court, Corona, CA 92879, OR fax to (909) 371-3052, OR email to forum@nutsvolts.com

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.

QUESTION INFO

To be considered

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

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

Information/Restrictions

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

Helpful Hints

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

anyone know where I can find plans or a kit?

#I1039 **John E. Wilford**
via Internet

I need a circuit that will track a changing voltage (+0.1 to +0.9 V) and allow me to use a potentiometer to create an off set of ± 0 to 3 millivolts. The sensed voltage fluctuates several times a second. I need to be able to adjust the offset to an average of 0.45 V. I have a supply voltage of 12 volts available; this circuit is to track the output of an automotive O2 sensor.

#I10310 **Bill Mayhar**
via Internet

I want to build a current sensing switch that will turn on an audio amp when my television is switched on with its remote. The switch might also be used with higher current devices such as an indicator on the heating elements in my hot water heater. I would like to use a pass-though type sensor (toroid transformer?) so as not to break the power circuit of the device being monitored.

Any pointers to such circuits would be appreciated.

#I10311 **William T. Stanton**
Ardmore, OK

I'm looking for a temperature sensing circuit that will light each of three LEDs at approximately 80 degrees F, 90 F, and 100 F.

#I10312 **Matthew Seltzer**
via Internet

I have two devices that connect via serial line, call them A and B. Each has its own mains-powered DC power supply, but in one device (B), power comes from an external connection. How do I protect device B against a supply polarity reversal, taking into account the ground path to device A through the serial line?

#I10313 **Luke Barker**
via Internet

I need to rebuild the rectifier/regulator in the charging system of an old motorcycle, which was destroyed by battery acid. I chipped away the epoxy from the circuit, but in the process, I gutted some of the components from the heatsink. I have only been able to make out a few of them — three SCRs (25 A, 400 V, TO-220 style), some 1 K resistors, a small 5 K pot, two small transistors (one is C2N5403, the other is burned up), and three small diodes (1N403).

What is the design of such a circuit that regulates the battery charging voltage even when the generator RPMs change? Does anyone have a replacement circuit I can use?

#I10314 **Craig**
via Internet

ANSWERS

[08033 - August 2003]

The PLL system of my Kenwood R-5000 SW receiver went out and I discovered that Kenwood OEM PLL boards are dreadfully expensive.

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

Here are some suggestions:

1. A possible answer may be available at **www.qth.net** Once there, from the 'select list,' choose Kenwood and search through the archives. Possibly, you may find the answer. If not, sign on to the Kenwood list and post the question. Many times, someone within the group will have the information. The Kenwood TS 440 had a generic VCO problem. With time, the 'goop' that held some components together became conductive. The solution was to remove the goop and replace some components.

2. Kenwood may have a service bulletin on this subject. Go to **www.kenwood.net**, jump to service bulletins and search.

3. If both of the above fail, look at the PLL board for 'cream color' hard goop (hard synthetic rubber) covering several components. Determine the circuit associated with this area and check in the service manual if it is a VCO. If indeed there is such a situation, this is probably the number one suspect.

The cream colored goop must be removed, and associated parts replaced. Kenwood Service Bulletin SB 973 and 974 describe the procedure for the TS 440. Use the details in Bulletin 973 on how to clean the goop.

Parts may be hard to find. A good source is: East Coast Transistor Parts, Inc., **www.eastcoasttransistor.com**; (516) 483-5742.

I hope this helps.

Mort Arditti
Los Angeles, CA

[08034 - August 2003]

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

The reason you connect at 26.4 or 28.8 when dial up your server is because you are using a POTS (plain old telephone service) line at both ends of your connection. In order to take advantage of speeds above 33.6, both the modems and the telephone lines between them must comply with the V.90 standard.

A V.90 connection is only supported on a communication path that has only one set of analog-to-digital and digital-to-analog conversions. I suspect that when you "dial out," you are referring to connecting to your Internet service provider. Your ISP has a bank of modems that connect though a digital circuit such as a T1 to the phone company's central office. The only way to remedy your low connection speed is to install a digital circuit to your server.

The most economical way to achieve this would be to order a ISDN BRI circuit from your phone company. Depending on the local phone company in your area, the price may be reasonable. This would

Continued on Page 104

FOR CINCINNATI AND VICINITY — Partly cloudy and warm, possi

"Just the (radio)

How Radio Stations Newspapers in

For most folks, the Great Depression conjures up images of soup kitchens, "Will Work for Food" signs, and city streets filled with throngs of unemployed men. However, the Depression years weren't all gloom and doom. While business and finance ground to a halt, technology was booming. In terms of new applications and demand, technology experienced almost unceasing growth throughout the 1930s.

As the decade progressed, electricity extended into rural areas. Automobiles became faster, safer, and more luxurious. Aviation records were broken as quickly as they were set. Advances in medicine, entertainment, and labor-saving appliances were announced almost daily, and two worlds' fairs showcased the marvels of technology to come.

Radio was the star of technology, and the growth industry of the 1930s, largely because it touched the lives of nearly everyone. So, as more powerful transmitters were built, more reliable receivers poured from the factories. Deco style came to radio cabinets, and phonographs found their way into them as manufacturers vied with one another to capture the marketplace. Novelties such as radio broadcasts from airplanes and radio receivers in automobiles quickly became the norm. Radio was not welcome in all corners, however. Newspapers found radio a definite threat. It competed for advertising dollars, and lured people away from reading newspapers. (Why pay a nickel for a paper, when you could listen to the news for free?) The wire services that supplied newspapers with news and photos refused to allow broadcasters access to their services. The one news service that was formed to supply radio stations with news — the Transradio News Service — was the object of lawsuits by the conventional news services almost before it started business. (Perhaps ironically, some of the largest newspapers were either buying or establishing radio stations.)


WLW
READO (RADIO PRINTING)
WLW
1939 · CINCINNATI, OHIO · HOME · OF "The Nation's Station"
VOL. 6 ..... NO. 8 ....
"July 25"
WEATHER FORECAST
FOR CINCINNATI AND VICINITY - PARTLY CLOUDY AND WARM, POSSIBLY SCATTERED THUNDERSHOWERS; SLIGHTLY COOLER LATE THURSDAY.
FOR OHIO - PARTLY CLOUDY FOLLOWED BY HEAVY SHOWERS AND THUNDERSTORMS; SLIGHTLY COOLER IN WEST PORTION.

Figure 1. To save space, radio-printed newspapers used simple text and graphics. The print quality was acceptable, although the thermal and carbon printing processes left smudges.

Despite this enmity, there were people who hoped to bridge a gap between radio and newspapers. One such person was an engineer named William G.H. Finch. His company — Finch Telecommunications Laboratories — had developed a simple and low-cost system for transmitting and receiving facsimile (now known as FAX) by radio. He applied for his first patent in 1935.

Radio facsimile was nothing new. The first radio facsimile system was patented in 1905, and its earliest application was transmitting weather maps and other data to ships at sea (a practice that continues today). By the early 1920s, news services were transmitting photos by radio facsimile (the first wirephotos). Between 1926 and 1932, RCA established radio facsimile service via shortwave between New York and London, San Francisco, Berlin, and Buenos Aires.

In theory, radio facsimile transmission involved little more than substituting a radio carrier wave for telephone wires. But the reality was not that simple. Transmitters and receivers were complicated and temperamental, and usually required trained operators. Until Finch's system, radio facsimile equipment was just too complex and costly for most commercial applications.

Finch had three rivals: RCA, General Electric, and Western Electric, each a corporate giant that might have crushed him. But as a 1937 article in *Business Week* put it, the Finch system was

"... the first to come out of the laboratory and into family parlors."

RCA had begun negotiations for online versions of four New York newspapers (*The New York Times*, *Herald Tribune*, *American*, and *World-Telegram*) in 1935. But even though experiments were made over the ensuing two years, no system was in place. Finch, on the other hand, had sold three US radio stations on testing his "radio printer" system by the end of 1937: WGH in Newport News, VA; WHO in Des Moines, IA; and KSTP of St. Paul, MN. The broadcasters received FCC permission to transmit radio facsimile signals in September of 1937, and the first transmissions of "radio-printed" news were made by KSTP the week of October 15, 1937. In November, the Iowa and Virginia stations were also broadcasting radio-printed news.

FAX, Ma'am"

Delivered Printed the 1930s

by Michael Banks

The typical radio facsimile unit was housed in what appeared to be (and usually was) a large radio or phonograph cabinet, with the radio receiver and printer housed as one unit within. The systems printed the news on a five-inch wide strip of paper that was either carbon-backed or heat-sensitive. Carbon-backed paper was backed up by a second layer of paper, on which images were made when a stylus touched the first layer. Heat-sensitive paper was similar to that used by 1970s printing calculators and FAX machines. The chemical treatment required for the latter gave the paper a gray or green tint. And the carbon-backed paper was a bit messy, but the quality was acceptable. Text and images were printed in black or dark gray in two columns. Photos and half-tone artwork didn't come through as well as in regular newspapers, but line art reproduced nicely.

In operation, the scanning end of a radio facsimile transmission involved a moving photocell passing over text and image to be scanned. Electrical signals from the photocell varied with the darkness or lightness of a given spot on the paper being scanned. A carrier wave was modulated with these signals, and the signal broadcast on an agreed-upon frequency. The typical range was 25 to 50 miles, although some experiments were successful at ranges of several hundred miles — though not consistently.

At the receiving end, the radio signals were converted to electrical impulses. A stepper motor on the printer moved a roll of paper 1/100-inch at a time, after which a stylus would glide across the paper's surface. When the stylus' driving mechanism received an electrical impulse (echoing what had been scanned), it pressed against the heat-sensitive or carbon-backed paper, leaving a black line. With this system, small dots or long lines could be placed on each line of the scrolling paper, and an image would gradually be built up, 1/100-inch at a time.

Participating broadcasters underwrote the entire effort as an experiment. Each radio station that signed on with Finch Laboratories placed 50 receiving sets in its broadcast area at a cost of $125.00 a piece — an investment of over $6,000.00 — the equivalent of nearly $200,000.00 today. And that didn't include scanning equipment and transmitter hook-ups. But broadcasters were optimistic, figuring revenue from advertising and subscriptions would justify the cost.

There were a few technical problems — the main ones being keeping the printer synchronized (minor), and static (major). As it turned out, facsimile broadcasts were not as "tolerant" of static as voice broadcasts. A burst of stat-

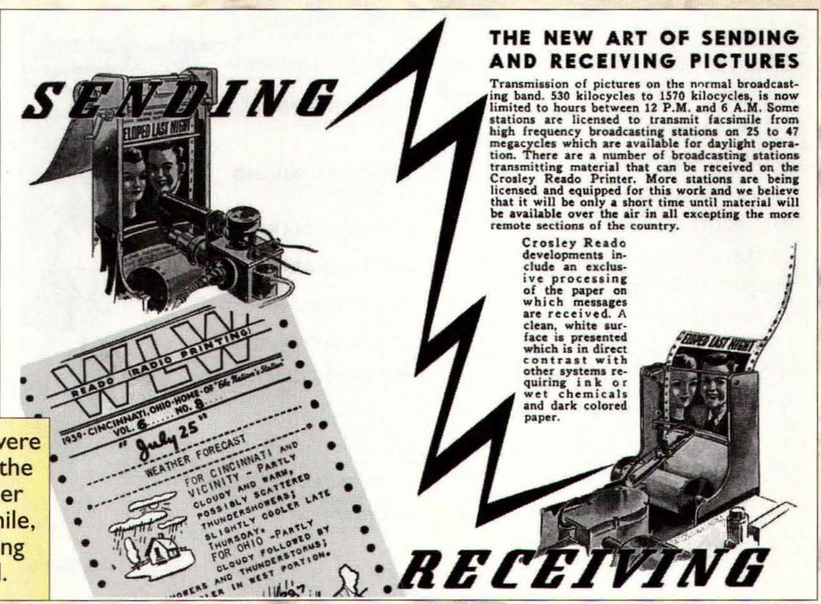
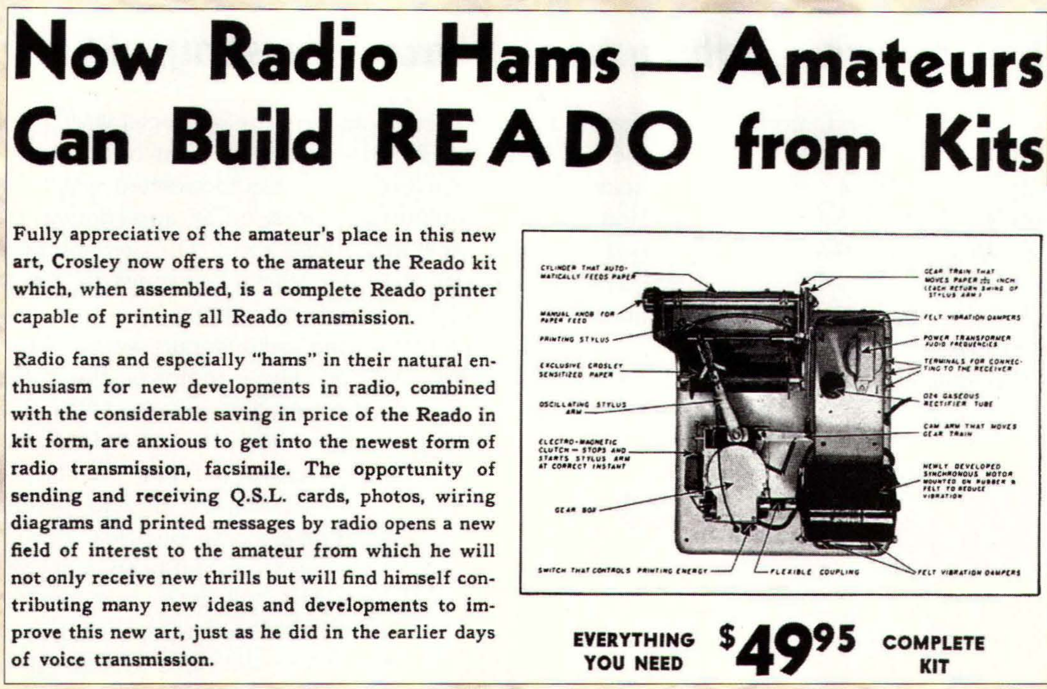


Figure 2. Efforts were made to educate the potential customer about radio facsimile, but without getting overly technical.


Now Radio Hams — Amateurs Can Build READO from Kits

Fully appreciative of the amateur's place in this new art, Crosley now offers to the amateur the Reado kit which, when assembled, is a complete Reado printer capable of printing all Reado transmission.

Radio fans and especially "hams" in their natural enthusiasm for new developments in radio, combined with the considerable saving in price of the Reado in kit form, are anxious to get into the newest form of radio transmission, facsimile. The opportunity of sending and receiving Q.S.L. cards, photos, wiring diagrams and printed messages by radio opens a new field of interest to the amateur from which he will not only receive new thrills but will find himself contributing many new ideas and developments to improve this new art, just as he did in the earlier days of voice transmission.

EVERYTHING YOU NEED $49.95 COMPLETE KIT

Figure 3. It was hoped that radio facsimile would have special appeal for radio amateurs, who were always seeking new projects.

ic lasting no more than a fraction of a second could wipe out several pages of a broadcast. Engineers were confident the problem could be solved, though.

By February of 1938, the Mutual Network stations (WOR in New York, WLW in Cincinnati, and WGN in Chicago) were conducting experiments with Finch equipment. Before long, their owners signed on to the program. WHK in Cleveland, Nashville's WSM, and California radio stations KMJ and KFBK of Fresno and Sacramento soon followed.

The FCC permitted stations to broadcast printed news between midnight and 6:00 am. At the time, radio stations routinely ended their broadcasts and signed off the air at 11:00 pm or midnight, so the time slot was ideal for delivering printed news before most people awoke. Stations at first used their assigned frequencies to broadcast the facsimile newspapers, but later changed or planned to change to high-frequency transmitters. Thus, WLW conducted experiments at 700 kilocycles, but planned to switch to 20,000 kilocycles for regular facsimile broadcasts. The St. Louis Post-Dispatch inaugurated its radio-printed version using its own experimental station — W9XZY — broadcasting at 31,600 kilocycles.

Once the receiving sets were in place, the cost to consumers was nominal. Rolls of heat-sensitive paper cost $1.00 each, and the estimated cost of the paper used in a week would be $0.10. (Paper consumption was projected to be about five feet per hour of transmission.) The cost of electrical usage in the average home would be increased by only $0.20 per week.

Most stations worked with local newspapers to provide the radio-printed news. (The exceptions were WHO and WGN, which used Transradio News Service as their news source.) Advertising sales would, of course, generate profits for all.

As enthusiasm grew, two radio manufacturers moved in for a share. RCA had experimented with radio facsimile messaging several years earlier, and lost little time getting back on the bandwagon with the manufacture of radio facsimile receivers. Crosley Radio Corporation, which was heavily committed on the broadcast end through its ownership of WLW, went a step farther. Its owner, Powel Crosley, Jr., licensed the Finch patents and started building a low-cost version of the Finch receiver. By January 1939, the Crosley factory had manufactured 500 sets, and set up an assembly line

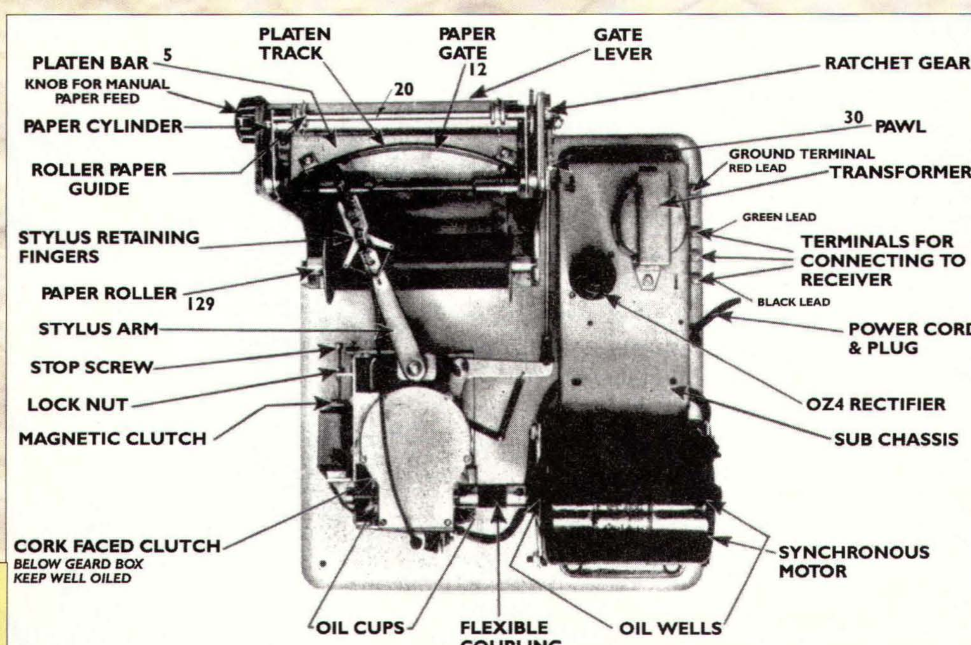


Figure 4. Detailed view of the printing mechanism from the Crosley Reado radio printer.

capable of turning out 100 sets a day. He dubbed the receivers and the service "Reado."

These moves by Crosley, whose inexpensive radio sets were, in large part, responsible for the immense popularity and growth of radio from 1921 on, were a huge vote of confidence for radio-printed news. In industry circles it was taken for granted that, if Powel Crosley, Jr., the man the press had dubbed "the Henry Ford of Radio," was involved in an endeavor, it had to be a sure thing.

As was typical of any Crosley product, there were certain distinctive touches to Reado. Beginning with his first radio sets in 1922, Powel Crosley, Jr., always tried to beat the market with lower price sets. Reado was no exception. Printers were set to retail at $79.50, and designed to work with any radio. For $10.00 more, you could have an optional electric timer to turn the system on and off at preset times. A radio in a matching cabinet was also available for an additional $60.00.

The man who found that he could use his decorative speaker housings to make decorative electric fans (thus saving money on design and component costs) found a similar way to reduce the production cost on Reados. The Reado printer was designed to fit into a Crosley radio cabinet, and to be compatible with any radio set. This meant that Reado customers didn't have to buy the radio and the printer together. It also meant that a certain Crosley radio model just happened to match the Reado's "... handsome cabinet, made of carefully-selected walnut veneers." This Crosley model was, of course, recommended for those wanting optimum performance.

Crosley was noted for including something innovative in products he made, whether it was a radio, car, airplane, or radio FAX receiver. In the case of Reado, Crosley developed an improved heat-sensitive paper that delivered crisp images on white paper. Also enhancing image quality was the fact that Reado machines printed a little slower than the Finch receivers — three feet per hour, rather than five.

All of this meant that radio FAX users everywhere would be assured of a better-performing product at a lower price — a Crosley hallmark.

With the factory in production, Crosley launched a complete business and marketing plan for the receivers and the broadcast service. In January 1939, he placed large ads for "Reado Radio Printing" in Cincinnati newspapers. Each ran from top to bottom of the newspaper page, and was close to the width of a Reado printout, more or less serving as a sample of the product.

The public was invited to daily demonstrations of the system from January 14 through January 24. The venue was the swank Hotel Gibson on Fourth Street in the center of Cincinnati. Although the newspaper ads noted that Reado units were "Sold for experimental use only," it was clear that this was a serious consumer product.

To round things out, the Crosley Reado was advertised with a clever motto: "Radio for the Eyes as well as the Ears." Radio facsimile printing was even demonstrated in the Crosley building at the 1939 New York World's Fair, alongside the Crosley Shelvador refrigerator and other appliances, radios, cameras, and the new Crosley automobile. All hosted by the Crosley Glamortone Gals, of course.

It appeared that the delivery of newspapers by radio broadcast was ready to roll, and that Crosley would be the leader in manufacturing the

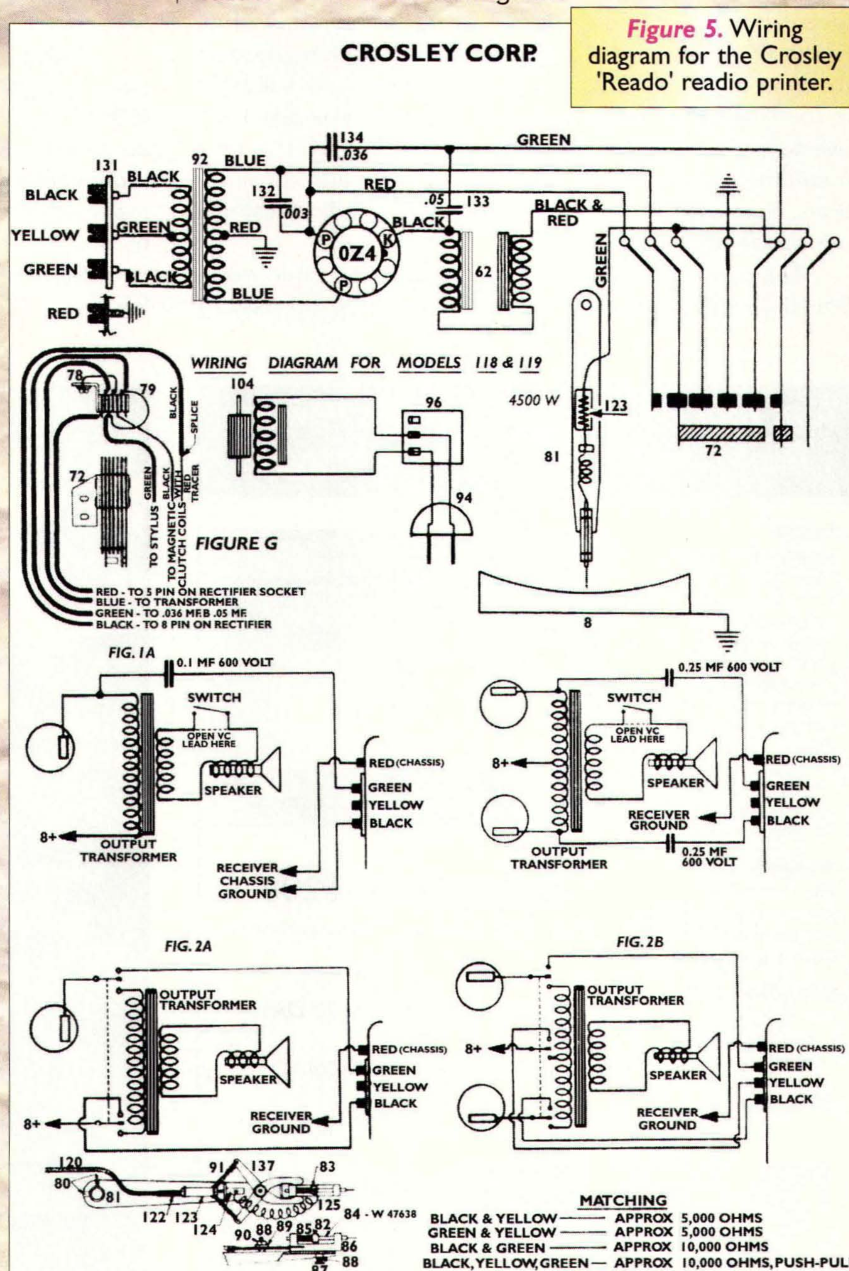


Figure 5. Wiring diagram for the Crosley 'Reado' readio printer.

CROSLEY READO
RADIO PRINTING

A Crosley engineering triumph in a new field that promises wide use and practical application. The facsimile system used by the Crosley Corporation was developed by Mr. W. G. H. Finch over a period of many years in his laboratory. The Crosley Reado incorporates many additional features which have been developed in the Crosley laboratories. And Crosley was the first to make these receivers available for reception in the home of experimental and demonstrative programs.

MODEL F1188 $79.50

CROSLEY READO PRINTER

The Reado Printer converts radio waves into text and pictures, printing on white paper practically anything that can be printed on a printing press. It can be used with any radio set that delivers 5 watts or more. The Printer can be easily attached to the receiver. Pictures are reproduced in excellent detail, similar to those in daily newspapers. Each hour of broadcasting produces approximately three feet of printed paper. Crosley Reado Printer is designed for the utmost simplicity, and is housed in a handsome cabinet of carefully selected walnut veneers. Provision is made for automatic time switch.

CROSLEY ELECTRIC TIME SWITCH

This electric clock and time switch fits into the Reado Printer cabinet and may be connected for automatic use either with the printer or with the sound receiver. The proper hour of any sound broadcast can be set and when the time arrives the receiving set will go on and produce the sound or facsimile program.

It is particularly desirable in early morning or late night reception to set the receiver and printer to come on and receive Reado programs for a scheduled period. Simply set the clock for any predetermined broadcast. The Reado clock will turn the receiver on at the beginning of the broadcast and off at its conclusion.

MODEL 758A $60.00

HIGH FIDELITY 2-BAND RADIO

We strongly recommend the use of this receiver in connection with the Reado Printer, as it incorporates automatic control of printing level which is vitally important to true, even printing and automatic operation. Seven-tube two-band superheterodyne intended for use of the ultra high frequency band (24 to 42 megacycles) as well as standard broadcast. Special type amplified automatic volume control insures practically constant output over a wide variation in input signal. Has outlets for attaching separate speaker, time switch, or phonograph record player. Has push button tuning for five favored stations. Smartly styled cabinet is center matched stump walnut and quarter stripe walnut veneer.

CROSLEY READO PAPER

Special rolls of paper for use with the Reado Printer, are available from Crosley dealers. This paper is an exclusive Crosley development and presents a clean surface with message in black and white. In the printing process the paper remains dry. It comes in rolls 4½ inches wide and is easily inserted in the printer as required. Reado Paper costs only $1.00 per roll.

MODEL 028 $10

Figure 6. The Crosley "Reado" radio facsimile system was sold in component form. The main unit — the printer — was also the most expensive, but could be used with any radio. For those for whom decor was important, there was a matching radio. A $10.00 timer rounded out the system (convenient if you went to bed early).

receivers. But fate conspired against Crosley, as well as Finch, RCA, and all the broadcasters who had invested so much in the radio facsimile system. Money was still tight in the late 1930s, and consumer response was less than overwhelming. This made advertisers leery of the new medium. Without strong advertiser support and subscriptions, the service was doomed. By 1940, radio facsimile newspaper delivery had ended.

The system might have been resurrected after World War II. By then, however, television was making its way into the nation's living rooms. Text and pictures by radio just couldn't compete with television's moving pictures and sound.

Still, William Finch hadn't lost his confidence in FAX as a mass communications medium, however. Right after World War II, he devised a new approach to transmitting newspapers. He intended to FAX them over telephone lines into the homes of millions of paying Americans.

Interestingly, his business plan included local and regional versions of the facsimile newspapers, plus one "super-newspaper" for national consumption. (Shades of USA Today!)

That didn't go over, either. Television and radio were more convenient, and people apparently preferred their newspapers on newsprint. Finch's company went bankrupt in 1952. (Fortunately, he was able to license some of this technology to RCA over the next few years.)

There's little left of radio facsimile-printed newspapers today, save for the odd receiver/printer in a radio collection or antique shop. In the 1940s and 1950s, radio amateurs used modified receiver/printers to pick up broadcasts of FAX weather reports to ships, but there really wasn't much use for them, otherwise. That's probably just as well. Even if radio-printed newspapers hadn't been killed by television, it would never have survived the Internet. NV

Catching Up With the DUMMIES®

by Edward B. Driscoll Jr.

These Dummies Want To Make Your Home Smart!

Interview With The Authors Of Smart Homes For Dummies

Learning about home automation can be a daunting task. Many of us start with an interest in one field (such as home theater or security), then want to learn more. It can be a slow-learning curve to get up to speed on lighting, security, electricity, whole-house audio and video, computers, and all the other areas that home automation incorporates. So in 1999, a couple of years into my odyssey of giving my home some smarts, I was thrilled to have stumbled over the book, *Smart Homes for Dummies*, by Danny Briere and Pat Hurley, now in a second edition released earlier this year. (UPDATE: 384 pages, soft cover, $19.95, published by UPDATE Wiley Publishing, Inc., ISBN: 0764525395, available online at **www.amazon.com**, **www.dummies.com**, as well as at your local bookseller.) Briere and Hurley have also released two new books: *Home Theater For Dummies* and *Wireless Home Networking For Dummies*. They're currently finishing another book for Wiley on Microsoft's Windows XP Media Center Edition Operation System, an OS which can either put a PC in the home theater, or run the equivalent of a home theater on a PC.

If you've been put off by the title and concept of this series ("Hey, I'm no dummy, I know enough about smart homes to be reading *Nuts & Volts*, for gosh sakes!"), then rest easy. Briere and Hurley's books are terrific summaries of all of the areas of home automation that will allow anyone to get "the big picture."

Focus on the Infrastructure

In *Smart Homes For Dummies*, Beire and Hurley focus on concepts and technologies rather than products, and especially on the infrastructure of a smart home — its network of low-voltage wires and wireless technologies. The idea is that you can always change the endpoints, and what gets attached to them later. As Briere says, "That's really what the goal of the book was — to put together a big picture view, and a design paradigm for people when they are approaching the topic of a home for 20 or 30 years. You know, people will put a 20- or 30-year roof on their house, but they don't think about that when they come to do their wiring or things they put in the wall.

"And that was one of the things that we really wanted to get into people's heads," Briere emphasizes. "Put something into the wall that will last 20, 30, or even 40 years, and worry about what you put on the endpoints later on. Because once the infrastructure is in the walls, you can change the endpoints and you can have all sorts of flexibility in them. But if you rip out walls later on, it gets really expensive."

Another key goal in Briere and Hurley's books was avoiding what they call "islands of technology." As Hurley says, "I think that a lot of people have some elements of 'smart' things in their homes. But not a lot of people have thought about tying those elements together in sort of a whole-home approach. And that's one of the things that you face — people have these islands of technology. They have a stereo system, DVD player, and Tivo, or ReplayTV box in their living room. But if they wanted to, and if they had designed a home network, they could share those technologies with other TV sets in the house — things like that. The endpoint technology is quite popular and people are coming around — I don't know if I have any numbers — but people are beginning to think in terms of the whole-home for a lot of these things. Still, most people have these things in their own little room."

Perhaps one reason for their emphasis on using home telecommunication networks to tie a smart home together is that unlike many home automation experts who come at home automation through their mastery of home-based technologies, Danny and Pat have made their careers in the telecommunication industry, prior to writing *Smart Homes for Dummies*. Briere is CEO of TeleChoice, Inc., which he started in 1985. "Today, just about every major telecom player in the world is our client," he says. And Pat Hurley is a consultant and DSL analyst for TeleChoice.

Thinking Outside of the Box

Their background has helped them to come up with a number of ideas that are "outside of the box" of the traditional home automation industry.

Their approach also grew out of a practical need to expand their own knowledge base. In the mid 1990s, Briere began to renovate his then recently purchased house in Maine, to convert it into what he calls a "'vacation home for the next 60 years' type of place." Briere often spends a month at a time both working out of there, and spending time with his family at his primary residence.

When Briere began to ask his contractor about what would be needed for a sophisticated home office in his vacation home, Briere says, "He didn't know anything. And we started talking to all sorts of people, and we went to various stereo stores, and other people, and couldn't really find anybody who knew anything."

Fortunately, Briere says that Pat Hurley, his friend and associate, "has a lot of background in tinkering and he's just very, very knowledgeable on the whole computer and networking side of the equation. It became almost a hobby trying to figure out how he could fix up my house. Finally we said, 'You know what? We learned all this great stuff.' At the time, we couldn't find any books on the topic, so we said, 'Why don't we write a book on the topic?!'"

And the rest is home automation history. Because Briere and Hurely had written previous books for IDG Books (now a part of Wiley Publishing, Inc.), the first edition of *Smart Homes for Dummies* was put on the fast track for publication, and released in mid 1999.

Home Automation

Ed: What's new in the updated edition of the home automation book?

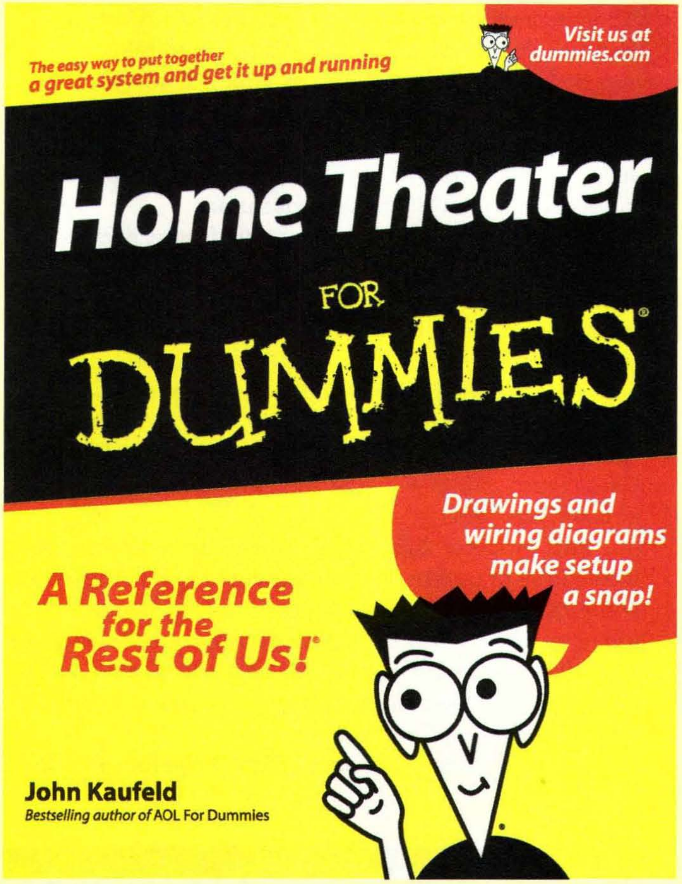
Danny: The biggest thing that's happened in the home automation book is the addition of WIFI. This has come down so far in price and has just invaded the home. And that invasion is going to continue. It's not just about putting an access point in your house. But about creating a wireless backbone, and then all of a sudden, everything starts hopping on board.

With a wireless backbone in the home, all of your video signals can come from one place. If you have an MCE Windows PC in one part of the house, it could hop on board that and transmit signals to other TV sets in the house. You might be able to have one PC running multiple TV sets. You might have the ability to dock your car when it comes into the garage with the wireless LAN and upload and download things. So if you're going to take a trip, you can download some movies to your car for your kids to watch. These are all very realistic things that you can do today, and the price points are just phenomenal. The sales volumes involved with WIFI are bringing the prices down for everything, for all these applications.

Another big change is the move from Cat-5 to Cat-5e to Cat-6. We're seeing improvements in the underlying wiring available for people to put in their homes. At some point, people need to draw a line in the sand and say, 'This is the type of wiring I'm putting in my house.' But as you get up in the Cat-6 and the higher level types of wiring, you have to treat those very carefully — you can't run them the same way you ran Cat-5 wiring or even RG-11 — the old Cat-3 type wiring — because it's just more sensitive to kinks in the cabling.

Pat: Another big change that has happened is the whole idea of putting in structured wiring has moved from something that just a few people did, to becoming very mainstream. Most new buildings now are having some form of structured wiring put in them. When we did the first edition of the book three years ago, it was still fairly limited to just high-end homes.

Danny: Three years ago, I didn't have four PCs for my



kids. I do now. Each kid has their own PC. They're coming home with homework assignments saying, 'Look this up on the Internet. Find me this.' My kids aren't that old — I've got two that are 10 and two that are six. The six-year-olds have become phenomenally adept at working around the computers.

Another thing that you're starting to see making an impact is the concept of the home server. The MCE platform is the early stage of that. You can use what I would call almost business-class software to meet certain applications. But to do a home server in your house, you really need to make sure that your wiring is set up well for that, because wireless can only go so far in accessing home servers.

Ed: And that was one of my questions — does it still make sense to put a LAN in, considering how ubiquitous wireless networking has become?

Danny: In a heartbeat, I would have no problem whatsoever telling somebody to spend the extra money, if they're building a new house, to put the wiring in the walls to support everything.

Pat: You won't mess around if you have Cat-5, Cat-5e, or Cat-6 now. Because I think there will always be a gap — if you look at the price of fast Ethernet equipment, it's basically nothing for a NIC for a 100-base-T Ethernet over Cat-5e. And I think the Gig-E pricing will start coming down to a really consumer-friendly level in the not too distant future. In a lot of consumer PCs, if you buy a Powerbook these days, it's going to have Gig-E built onboard. And the infrastructure really doesn't cost any more to get that higher speed, if you have Cat-5e or Cat-6. You have a lot of growth potential in your wired infrastructure.

Wireless is getting better. And yes, you can potentially get 54 megabits a second out of 802.11G. But in the real world, you're still getting maybe 20-25 megabits per second, and that's really pushing it, if you want to do something like sending HDTV video over your network. There's not really a quality of service mechanism yet. I think that will be solved over time, but I think that you will always have a speed advantage on a wired network, and it always makes sense to put it in, if you can.

Ed: I guess wired isn't going away — it sounds like, in the next two or three years, people could be having gigabit Ethernets in their home.

Danny: Using wire line — that's right. I think that's going to be very, very common, along with wireless, which is great for getting the car to log on, for sitting by the pool and logging on, for sitting in bed and logging on, and for being able to go peer-to-peer.

Ed: When I read the *Dummies* book, I was surprised that you weren't all that big on fiber optics in the home. Has that changed any?

Pat: I think that if you look at equipment that's in the home, or that's being built for the home, there's very little that actually uses fiber. The only place that you really see fiber connections in the home is if you're using certain kinds of audio or home theater equipment and put a Toslink fiber optics link between a decoder and a surround sound receiver or DVD player, or something like that. And beyond that, there just isn't a standard — there just isn't a way of doing it in the home that's been widely agreed upon.

That's why we made that recommendation in the book, because eventually people will find a way to put fiber in the walls, and transfer video and things like that over fiber. Right now, there's no future-proof, guaranteed way of doing an installation of that kind of stuff and making it so that it will work in the future, when something actually comes about.

The one thing that we recommended in the book, and we still believe, is that you put the conduit in, you put some pull-cables in so that if something comes along, you can upgrade to it. At this point in time, you can buy fiber for your walls. People who sell some of those kits that combine home networking wires with speaker wire and phone wires and Cat-5 will throw fiber in there, but there's really nothing that you can buy as a consumer that you can hook up to it right now.

The Home Theater PC

Ed: *The Home Theater For Dummies* book, and the

Authors of *Smart Homes For Dummies,* **left** Pat Hurley, **right** Danny Brierre

book you're currently working on, about Microsoft's Windows MCE OS are both built around the idea of PCs in the home theater. I know in the past, the home theater PC never really took off commercially. Phillips introduced one commercially a few years ago, as did others, but they really didn't seem to have a long shelf life. Do you think that having Microsoft involved with a proprietised operating system will help push them into the home theater?

Pat: I think it will. I don't know if it's a good thing or a bad thing, because certainly some people would rather do it themselves, but if you play with the Media Center edition, it's really well-optimized for display on a TV — it's very well integrated. The remote comes with it, you don't have to try and program your audio jukebox program, and your DVD and PVR programs to work together in a seamless way to use the remote control very easily. So Media Center makes it a lot easier — it puts a consumer-level front-end on the stuff that you could already do yourself, if you were geeky enough to get to do it. So I think it makes it more friendly to the average consumer.

I also think that just the fact that it's on XP and not on earlier operating systems like those models from three or four years ago, makes it a little more stable and you can run it for days at a time without having to re-boot all the time.

Ed: What do you need for a monitor for these things? Can you plug it into an NTSC monitor, or do you need HDTV?

Pat: Actually, every one of them will plug into an NTSC monitor. It depends on the videocard, and what kind of things you can do with a higher resolution monitor. They don't explicitly support HDTV in the current version, though you could have your videocard do a progressive scan monitor, and upconvert what your NTSC content on the machine is.

Danny: Clearly, that's the direction they want to go — you've got the cost of plasma screens and HDTV coming down, almost like it's falling off a cliff, right? So it's coming down really, really fast. At the same time, you're seeing efforts not only by Microsoft, but all the vendors to be able to expand their support for being able to do everything you're doing on a computer monitor, and being able to do that on your TV set.

So the question is, "What, what happens if you go and buy a PC today to do a lot of your home theater needs? Is it going to be obsolete in a year, or will I have to do a 'fork-lift upgrade' in a year?" And I think the answer to that is no. Because it's all very modular, and if you need a new card, you can add a new card. And if you need some more storage, you can add it to a USB port on there, and add some USB storage. There are a lot of options that are opening up with wireless to be able to communicate around the house.

So I think that the reason why you've seen the big jump in the number of players that are supporting this software (and major players) is because it's hitting the mainstream. And I think another reason why now, as opposed to two years ago, is that two years ago, a lot of people were still buying their first PC. The media center PC is really geared toward people buying their second and third PCs. They'd love it to be everyone's first PC, and I actually think that anybody buying their first PC should seriously consider getting an MCE PC, particularly if they live in an apartment or a small place, because they can really play a dual role of being a PC and an entertainment center. It's pretty fun stuff.

You have to look at the demographics — the media center PC is a higher-end demographic. Those people have been already migrating up to plasma, to the nicer TV sets, and to some of the projector stuff. It's the mid to high end of the marketplace. But somebody who doesn't have a lot of money and is buying their first PC, they're probably not going to be buying an MCE.

Pat: Or they might be buying an MCE with a 19-inch LCD screen and using it in a small room to watch TV or watch movies — things like that.

Ed: So an MCE system could be a home theater in your PC, as opposed to a PC in your home theater?

Pat: Yes. I think that part of the target market for MCE, and one of the markets that they've had more success in, is people in dorm rooms and small apartments, where you just buy a relatively big monitor, you plug your cable TV into it, you rip all your CDs onto it, and if you're not sitting 15 feet away, then the picture is big enough. If you're sitting at your desk, you have a relatively good home theater-type experience. They come with surround sound speakers in a lot of cases, and you get sort of a mini-home theater.

But it can go either way — you can have the monitor and you can also separately hook it up to your big screen TV. You can hook it up to your big screen TV only, and not really use it for productivity applications that much. It's pretty flexible about how you use it. **NV**

BIPOLAR TRANSISTOR COOKBOOK — PART 5

Ray Marston describes a variety of practical oscillator and white noise waveform generator circuits in this month's edition of an eight-part series.

by Ray Marston

The two most widely used types of transistor waveform generator circuits are the oscillator types that produce sine waves and use transistors as linear amplifying elements, and the multivibrator types that generate square or rectangular waveforms and use transistors as digital switching elements.

This month's installment describes practical ways of using bipolars in the linear mode to make simple, but useful sine wave and white-noise generator circuits. Next month's edition of the series will deal with practical multivibrator types of bipolar waveform generator circuits.

OSCILLATOR BASICS

To generate reasonably pure sine waves, an oscillator has to satisfy two basic design requirements, as shown in Figure 1. First, the output of its amplifier (A1) must be fed back to its input via a frequency-selective network (A2) in such a way that the sum of the amplifier and feedback network phase shifts equals zero degrees (or 360°) at the desired oscillation frequency, i.e., so that $x° + y° = 0°$ (or 360°). Thus, if the amplifier generates 180° of phase shift between input and output, an additional 180° of phase shift must be introduced by the frequency-selective network.

The second requirement is that the amplifier's gain must exactly counter the losses of the frequency-selective feedback network at the desired oscillation frequency, to give an overall system gain of unity, e.g., A1 x A2 = 1. If the gain is below unity, the circuit will not oscillate, and if greater than unity, it will be over-driven and will generate distorted waveforms. The frequency-selective feedback network usually consists of either a C-R or L-C or crystal filter; practical oscillator circuits that use C-R frequency-selective filters usually generate output frequencies below 500 kHz; ones that use L-C frequency-selective filters usually generate output frequencies above 500 kHz; ones that use crystal filters generate ultra-precise signal frequencies.

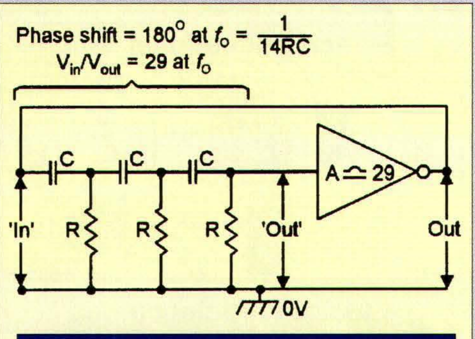


Figure 2. Third-order, high-pass filter used as the basis of a phase-shift oscillator.

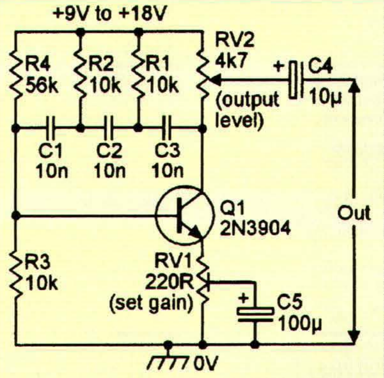


Figure 3. 800 Hz phase-shift oscillator.

C-R OSCILLATORS

The simplest C-R sine wave oscillator is the phase-shift type, which usually takes the basic form as shown in Figure 2. Here, three identical C-R high-pass filters are cascaded to make a third-order filter that is inserted between the output and input of the inverting (180° phase shift) amplifier; the filter gives a total phase shift of 180° at a frequency, fo, of about 1/(14RC), so the complete circuit has a loop shift of 360° under this condition and oscillates at fo if the amplifier has enough gain (about x29) to compensate for the filter's losses and, thus, give a mean loop gain fractionally greater than unity.

Note in Figure 2 that each individual C-R high-

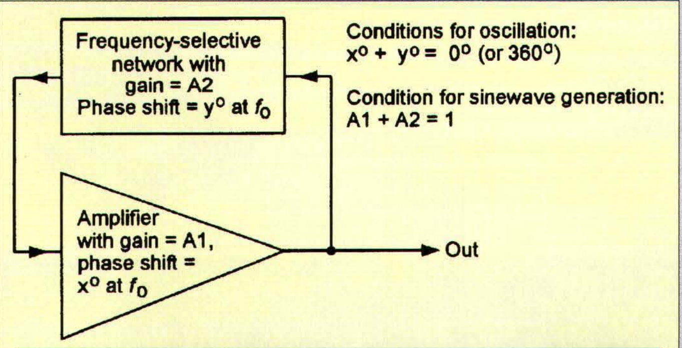


Figure 1. Essential circuit and conditions needed for sine wave generation.

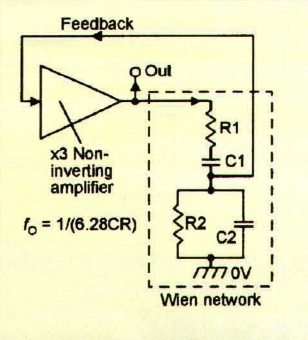


Figure 4. Basic Wien oscillator circuit.

pass filter stage tends to pass high-frequency signals, but rejects low-frequency ones. Its output is 3 dB down at a break frequency of 1/(2 RC), and falls at a 6 dB/octave rate as the frequency is decreased below this value. Thus, a basic 1 kHz filter gives 12 dB of rejection to a 250 Hz signal, and 20 dB to a 100 Hz one. The phase angle of the output signal leads that of the input and equals arctan 1/(2fCR), or +45° at fc. Each C-R stage is known as a first-order filter. If a number (n) of such filters are cascaded, the resulting circuit is known as an "nth-order" filter and has a slope, beyond fc of (n x 6 dB)/octave.

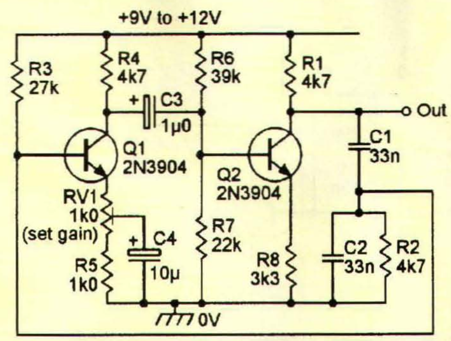


Figure 5. Practical 1 kHz Wien oscillator.

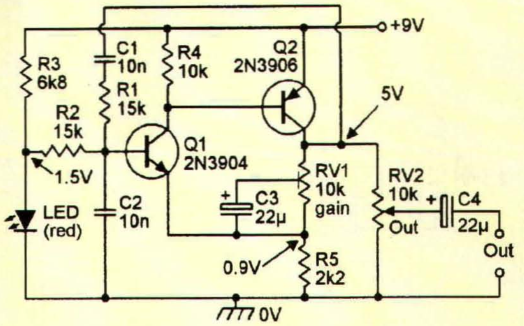


Figure 6. 1 kHz Wien bridge sine wave generator with variable-amplitude output.

Figure 3 shows the circuit of a practical 800 Hz phase-shift oscillator that can operate from any DC supply in the 9V to 18V range. To initially set up the circuit, simply trim RV1 so that the circuit generates a reasonably pure sine wave output as seen on an oscilloscope — the signal's output level is fully variable via RV2.

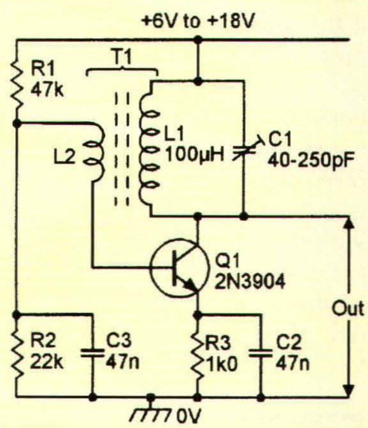


Figure 7. Tuned collector feedback oscillator.

Major disadvantages of simple phase-shift oscillators of the Figure 3 type are that they have fairly poor inherent gain stability, and that their operating frequency can not easily be made variable. A far more versatile C-R oscillator can be built using the Wien bridge network.

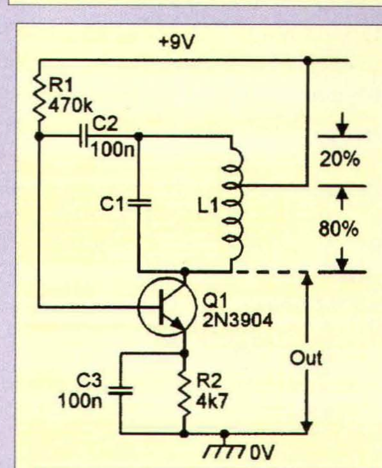


Figure 8. Basic Hartley oscillator.

Figure 4 shows the basic elements of the Wien bridge oscillator. The Wien network consists of R1-C1 and R2-C2, which have their values balanced so that C1=C2=C, and R1=R2=R. This network's phase shifts are negative at low frequencies, positive at high ones, and zero at a center frequency of 1/(6.28CR), at which the network has an attenuation factor of three. The network can thus be made to oscillate by connecting a non-inverting x3 high input impedance amplifier between its output and input terminals, as shown in the diagram.

Figure 5 shows a simple fixed-frequency Wien oscillator in which Q1 and Q2 are both wired as low-gain common-emitter amplifiers. Q2 gives a voltage gain slightly greater than unity and uses Wien network resistor R1 as its collector load and Q1 presents a high input impedance to the output of the Wien network and has its gain variable via RV1. The component values show that the circuit oscillates at about 1 kHz — in use, RV1 should be adjusted so that a slightly distorted sine wave output is generated.

Figure 6 shows an improved Wien oscillator design that consumes 1.8 mA from a 9V supply and has an output amplitude that is fully variable up to 6V peak-to-peak via

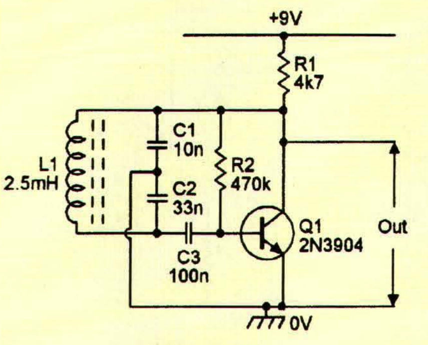


Figure 9. 37 kHz Colpitts oscillator.

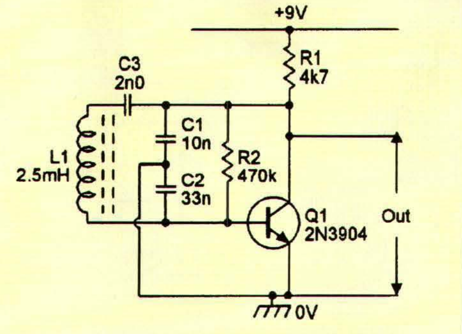


Figure 10. 80 kHz Gouriet or Clapp oscillator.

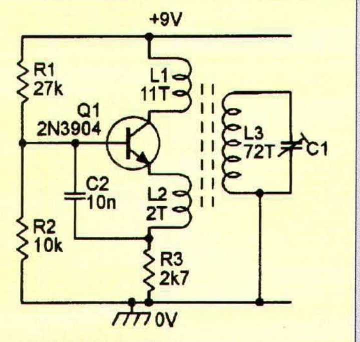


Figure 11. Basic Reinartz oscillator.

RV2. Q1-Q2 are a direct-coupled complementary common-emitter pair, and give a very high input impedance to Q1 base, a low output impedance from Q2 collector, and non-inverted voltage gains of x5.5 DC and x1 to x5.5 AC (variable via RV1). The red LED generates a low-impedance 1.5V that is fed to Q1 base via R2 and therefore biases Q2's output to a quiescent value of +5V. The R1-C1 and R2-C2 Wien network is connected between Q2's output and Q1's input, and in use RV1 is simply adjusted so that, when the circuit's output is viewed on an oscilloscope, a stable and visually clean waveform is generated. Under this condition, the oscillation amplitude is limited at about 6V peak-to-peak by the onset of positive-peak clipping as the amplifier starts to run into saturation. If RV1 is carefully adjusted, this clipping can be reduced to an almost imperceptible level, enabling good-quality sine waves, with less than 0.5% THD, to be generated.

The Figure 6 circuit can be modified to give limited-range variable-frequency operation by reducing the R1 and R2 values to 4.7K and wiring them in series with ganged 10K variable resistors. Note, however, that variable-frequency Wien oscillators are best built using op-amps or other linear ICs, in conjunction with automatic-gain-control feedback systems, using various standard circuits of this type that have been published in previous editions of this magazine.

L-C OSCILLATORS

C-R sine wave oscillators usually generate signals in the 5 Hz to 500 kHz range. L-C oscillators usually generate them in the 5 kHz to 500 MHz range, and consist of a frequency-selective L-C network that is connected into an amplifier's feedback loop.

The simplest L-C transistor oscillator is the tuned collector feedback type shown in Figure 7. Q1 is wired as a common-emitter amplifier, with base bias provided via R1-R2 and with emitter resistor R3 AC-decoupled via C2. L1-C1 forms the tuned collector circuit, and collector-to-base feedback is provided via L2, which is inductively coupled to L1 and provides a transformer action. By selecting the phase of this feedback signal, the circuit can be made to give zero loop phase shift at the tuned frequency, so that it oscillates if the loop gain (determined by the turns ratio of T1) is greater than unity.

A feature of any L-C tuned circuit is that the phase relationship between its energizing current and induced voltage varies from -90° to +90°, and is zero at a center frequency given by $f = 1/(2 LC)$. Thus, the Figure 7 circuit gives zero overall phase shift, and oscillates at, this center frequency. With the component values shown, the frequency can be varied from 1 MHz to 2 MHz via C1. This basic circuit can be designed to operate at frequencies ranging from a few tens of Hz by using a laminated iron-cored transformer, up to tens or hundreds of MHz using RF techniques.

CIRCUIT VARIATIONS

Figure 8 shows a simple variation of the Figure 7 design — the Hartley oscillator. Its L1 collector load is tapped about 20% down from its top, and the positive supply rail is connected to this point; L1 thus gives an autotransformer action, in which the signal voltage at the top of L1 is 180° out of phase with that at its low (Q1 collector) end. The signal from the top of the coil is fed to Q1's base via C2, and the circuit thus oscillates at a frequency set by the L-C values.

Note from the above description that oscillator action depends on some kind of common signal tapping point being made into the tuned circuit, so that a phase-splitting autotransformer action is obtained. This tapping point does not have to be made into the actual tuning coil, but can be made into the tuning capacitor, as in the Colpitts oscillator cir-

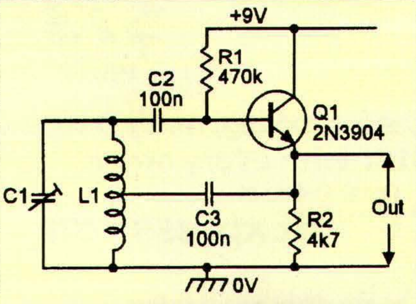


Figure 12. Emitter follower version of the Hartley oscillator.

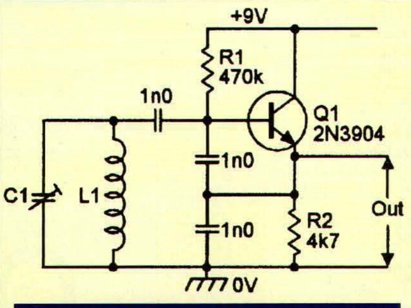


Figure 13. Emitter follower version of the Colpitts oscillator.

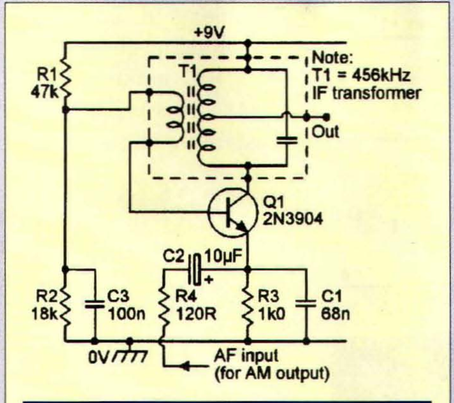


Figure 14. 465 kHz BFO with AM facility.

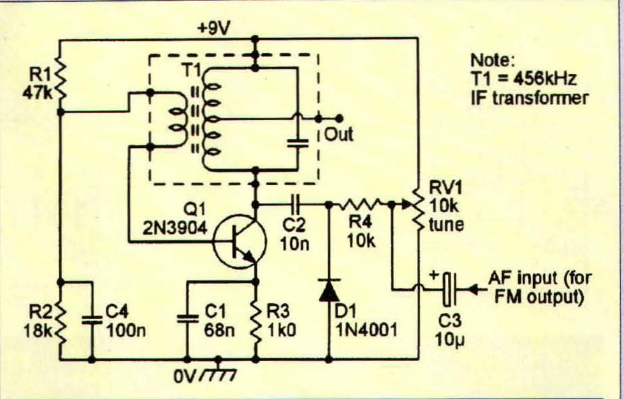


Figure 15. 465 kHz BFO with varactor tuning and FM facility.

cuit shown in Figure 9. With the component values shown, this particular circuit oscillates at about 37 kHz.

A modification of the Colpitts design, known as the Clapp or Gouriet oscillator, is shown in Figure 10. C3 is wired in series with L1 and has a value that is small relative to C1 and C2. Consequently, the circuit's resonant frequency is set mainly by L1 and C3, and is almost independent of variations in transistor capacitances, etc. The circuit thus gives excellent frequency stability. With the component values shown, it oscillates at about 80 kHz.

Figure 11 shows a Reinartz oscillator, in which the tuning coil has three inductively-coupled windings. Positive feedback is obtained by coupling the transistor's collector and emitter signals via windings L1 and L2. Both of these inductors are coupled to L3, and the circuit oscillates at a frequency determined by L3-C1. The diagram shows typical coil-turns ratios for a circuit that oscillates at a few hundred kHz.

Finally, Figures 12 and 13 show emitter follower versions of Hartley and Colpitts oscillators. In these circuits, the transistors and L1-C1 tuned circuits each give zero phase shift at the oscillation frequency, and the tuned circuit gives the voltage gain necessary to ensure oscillation.

MODULATION

The L-C oscillator circuits of Figures 7 to 13 can easily be modified to give modulated (AM or FM) rather than continuous-wave (CW) outputs. Figure 14, for example, shows the Figure 7 circuit modified to act as a 456 kHz beat-frequency oscillator (BFO) with an amplitude-modulation (AM) facility. A standard 465 kHz transistor IF transformer (T1) is used as the L-C tuned circuit, and an external AF signal can be fed to Q1's emitter via C2, thus effectively modulating Q1's supply voltage and thereby amplitude-modulating the 465 kHz carrier signal. The circuit can be used to generate modulation depths up to about 40%. C1 presents a low impedance to the 465 kHz carrier but a high impedance to the AF modulation signal.

Figure 15 shows the above circuit modified to give a frequency-modulation (FM) facility, together with varactor tuning via RV1. 1N4001 silicon diode D1 is used as an inexpensive varactor diode which, when reverse biased (as an inherent part of its basic silicon diode action) inherently exhibits a capacitance (of a few tens of pF) that decreases with applied reverse voltage. D1 and blocking capacitor C2 are wired in series and effectively connected across the T1 tuned circuit (since the circuit's supply rails are shorted together as far as AC signals are concerned).

Consequently, the oscillator's center frequency can be varied by altering D1's capacitance via RV1, and FM signals can be obtained by feeding an AF modulation signal to D1 via C3 and R4.

CRYSTAL OSCILLATORS

Crystal-controlled oscillators give excellent frequency accuracy and stability. Quartz crystals have typical Q values of about 100,000 and provide about 1,000 times greater stability than a conventional L-C tuned circuit. Their operating frequency (which may vary from a few kHz to 100 MHz) is determined by the mechanical dimensions of the crystal, which may be cut to give either series or parallel resonant operation. Series-mode devices show a low impedance

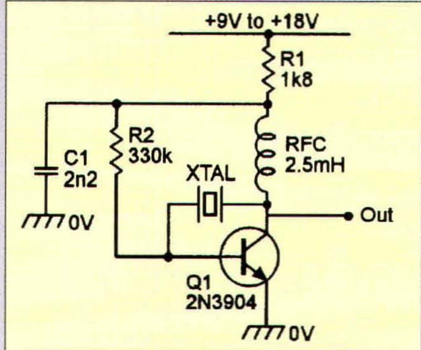


Figure 16. Wide-range Pierce oscillator uses parallel-mode crystal.

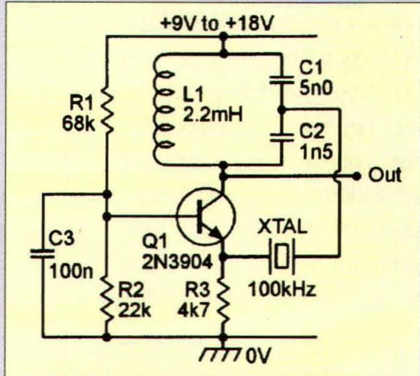


Figure 17. 100 kHz Colpitts oscillator uses series-mode crystal.

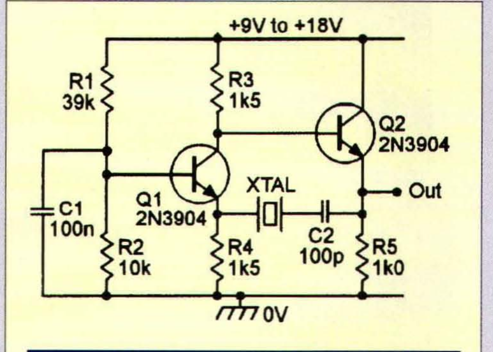


Figure 18. Wide-range (50 kHz-10 MHz) oscillator can be used with almost any series-mode crystal.

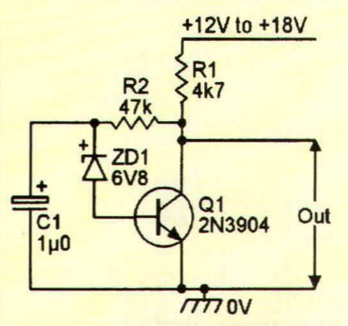


Figure 19. Transistor-Zener white noise generator.

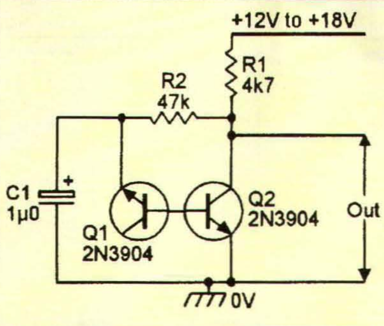


Figure 20. Two-transistor white noise generator.

at resonance — parallel-mode types show a high impedance at resonance.

Figure 16 shows a wide-range crystal oscillator designed for use with a parallel-mode crystal. This is actually a Pierce oscillator circuit, and can be used with virtually any good 100 kHz to 5 MHz parallel-mode crystal without need for circuit modification.

Alternatively, Figure 17 shows a 100 kHz Colpitts oscillator designed for use with a series-mode crystal. Note that the L1-C1-C2 tuned circuit is designed to resonate at the same frequency as the crystal, and that its component values must be changed if other crystal frequencies are used.

Finally, Figure 18 shows an exceptionally useful two-transistor oscillator that can be used with any 50 kHz to 10 MHz series-resonant crystal. Q1 is wired as a common-base amplifier and Q2 as an emitter follower, and the output signal (from Q2 emitter) is fed back to the input (Q1 emitter) via C2 and the series-resonant crystal. This excellent circuit will oscillate with any crystal that shows the slightest sign of life.

WHITE NOISE GENERATORS

One useful linear but non-sinusoidal waveform is that known as white noise, which contains a full spectrum of randomly generated frequencies, each with equal mean power when averaged over a unit of time. White noise is of value in testing AF and RF amplifiers, and is widely used in special-effects sound generator systems.

Figure 19 shows a simple white noise generator that relies on the fact that all zener diodes generate substantial white noise when operated at a low current. R2 and ZD1 are wired in a negative-feedback loop between the collector and base of common-emitter amplifier Q1, thus stabilizing the circuit's DC working levels, and the loop is AC-decoupled via C1. ZD1 thus acts as a white noise source that is wired in series with the base of Q1, which amplifies the noise to a useful level of about 1.0 volts, peak-to-peak. Any 5.6V to 12V zener diode can be used in this circuit.

Figure 20 is a simple variation of the above design, with the reverse-biased base-emitter junction of a 2N3904 transistor (which "zeners" at about 6V) used as the noise-generating zener diode. **NV**

Reader Feedback

Continued from Page 6

processor Alpha based machine that resides in my basement along with four other single processor machines. Microsoft — as much as I personally loathe anything related to Microsoft — released NT for both Intel and DEC Alpha processors in the mid-1990s. The Alpha can also support/run other operating systems such as OpenVMS, UNIX, and Linux. If your magazine is going to publish claims for new equipment, it should first investigate those claims for validity!

Brian Schenkenberger
via Internet

In the blurb, I said it is "billed as featuring the world's first 64-bit desktop processor," which is a standard way of indicating that the information came from the vendor.

Plus, you have to take this in context. We're talking about consumer-level PCs here, not commercial-grade workstations. I never knew any individuals who could afford a DEC machine. In the old days, I wanted a Sun Sparkstation, but could just barely pay for a Mac.

Jeff Eckert
Techknowledgey 2003

Dear Nuts & Volts:

In reference to the Oct. 2003 Q&A column, the second zero crossing detector circuit has a serious error in the orientation of the full wave bridge rectifier. As shown, the bridge will provide a direct short circuit across the AC input on the first half cycle in which the upper AC line is positive with respect to the lower line. Should someone build this circuit and connect it to their AC house power, they will be treated to a real light, sound, and smoke show. The bridge symbol needs to be rotated 90 degrees counter-clockwise.

David J. Prestel
via Internet

Beginning this month, readers will notice the "Just For Starters" column is now penned by Mark Balch. Mark is an experienced writer and has had one book on digital logic published by McGraw-Hill. Our previous author, George Whitaker, has left to focus on other endeavors, though we hope to publish future work by him.

— Editor Dan

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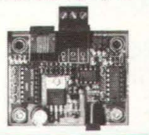

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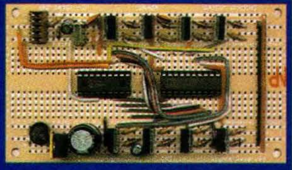

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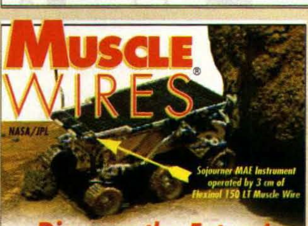

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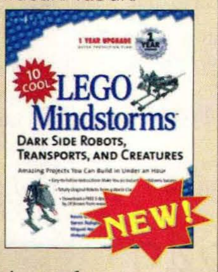
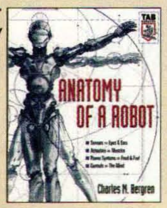


Okay, you bought the kit for yourself or one of your kids. You used the instructions in the box to build a robot or two. Now what? You may not be ready to design and build your own robots, but you don't want to build the same robot over again. This book is the perfect way to build additional projects from the same kit, and then improvise and design your own. Ten cool projects — one hour each ... perfect! **$24.95**

Anatomy of a Robot

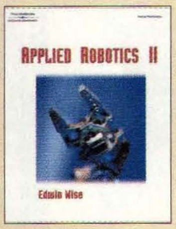
by Charles Bergren



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

Applied Robotics II

by Edwin Wise



Instructive illustrations, schematics, part numbers, and sources are also provided, making this book a "must" for advanced builders with a keen interest in moving from simple reflexes to autonomous, AI-based robots. Create larger and more useful mobile robots! Ideal for serious hobbyists, *Applied Robotics II* begins by discussing PMDC motor operation and criteria for selecting drive, arm, hand and neck motors **$41.95**

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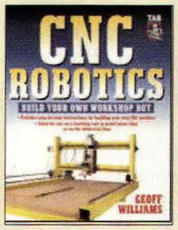
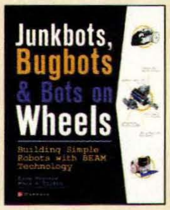


CNC Robotics gives you step-by-step illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80 percent of the price of an off-the-shelf bot — and that can be customized to suit your purposes exactly, because you designed it. Written by an accomplished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

JunkBots, Bugbots, and Bots on Wheels: Building Simple Robots With BEAM Technology

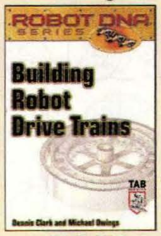
by David Hrynkiw / Mark Tilden



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

Building Robot Drive Trains

by Dennis Clark / Michael Owings



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

Everything you need to build your own robot drive train:

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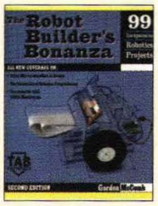

A major revision of the bestselling "bible" of amateur robotics building — packed with the latest in servo motor technology, microcontrolled robots, remote control, Lego Mindstorms Kits, and other commercial kits. **$24.95**

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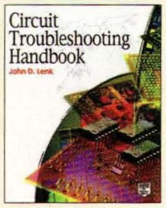

When it comes to troubleshooting, no other book even comes close — hundreds of circuits are covered in this exhaustive handbook. Heavily illustrated with diagrams and schematics, it uses an easy-to-follow format to help readers understand and troubleshoot a wide range of circuit types, and provides proven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

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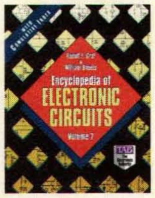

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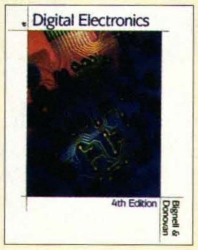

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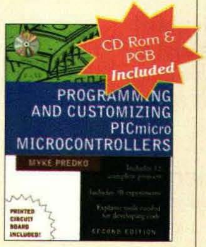

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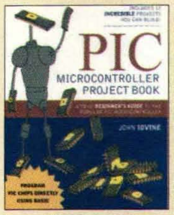

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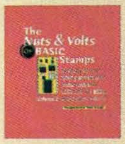

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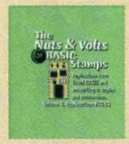

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Volume 3 is new and contains columns 76-92!

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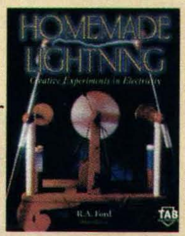

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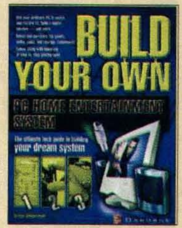

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An STMicroelectronics R&D group in Italy recently disclosed details of an advanced research program aimed at leveraging nanotechnology toward the manufacture of lower-cost solar cells. In an unexpected departure, the ST engineers are actually shooting for lower efficiencies (10% vs. the current highs of 15-20%) in the cells, but at dramatically decreased manufacturing costs. Square in their sights is the burning of fossil fuels which produce electricity at 1/10th the cost of current solar cell technologies.

The ST team is following two approaches, the most radical mimics a full organic approach, involving a mixture of electron-acceptor and electron-donor materials (Fullerene and organic copper, respectively.) The nanostructure of this blend is crucial for cell performance, as the materials have to be in intimate contact at distances below 10 nm. This is patterned after the electron collecting method of alternating single and double bonds in the chlorophyll molecule of plants. For more information visit the ST website, **www.st.com/stonline/**

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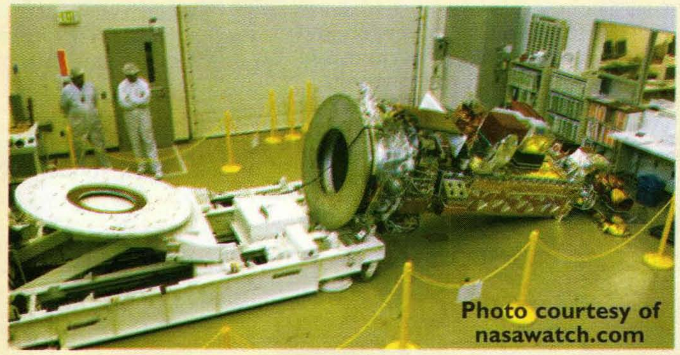

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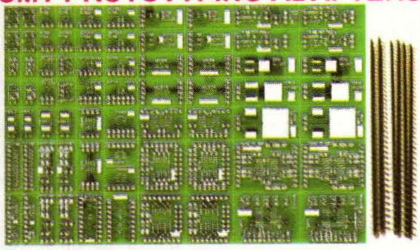

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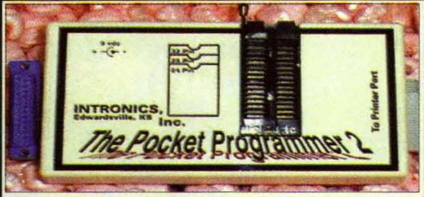

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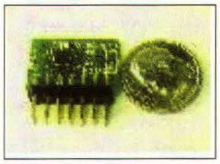

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Continued from Page 80

ended up on Sept. 6, 2003. Normally affixed by 24 bolts on its base to the white "turn over cart," the satellite slipped off and fell three feet during hydraulic repositioning from vertical to horizontal alignment. Two days earlier, technicians working on a different satellite removed the bolts to use on the same type of turn over cart, but without proper documentation. Unfortunately, the NOAA team then failed to verify the satellite configuration before repositioning — thus the mishap.

The satellite is part of the polar-orbiting environmental satellite program (POES) which monitors the Earth's weather and climate. It was originally scheduled to launch in 2008 for a four year mission. Significant test and rework will need to be performed on the $239 million spacecraft to determine the extent of damage due to shock and vibration. Image courtesy of **www.nasawatch.com**

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Basics For Beginners

Just For Starters

Introduction to Synchronous Logic Design

Putting smarts into hardware requires an understanding of synchronous logic design concepts in addition to the basics of Boolean functions (AND, OR, etc.). Boolean equations provide the means to transform a set of inputs into deterministic results. However, these equations have no ability to store the results of previous calculations upon which new calculations can be made. Digital systems operate by maintaining state to advance through sequential steps in an algorithm. State is the system's ability to keep a record of its progress in a particular sequence of operations. A system's state can be as simple as a counter or an accumulated sum.

State-full logic elements called flip-flops are able to indefinitely hold a specific state — 0 or 1 — until a new state is explicitly loaded into them. Flip-flops load a new state when triggered by the transition of an input clock. A clock is a repetitive binary signal with a defined period that is composed of 0 and 1 phases as shown in Figure 1. In addition to a defined period, a clock also has a certain duty cycle — the ratio of the duration of its 0 and 1 phases to the overall period.

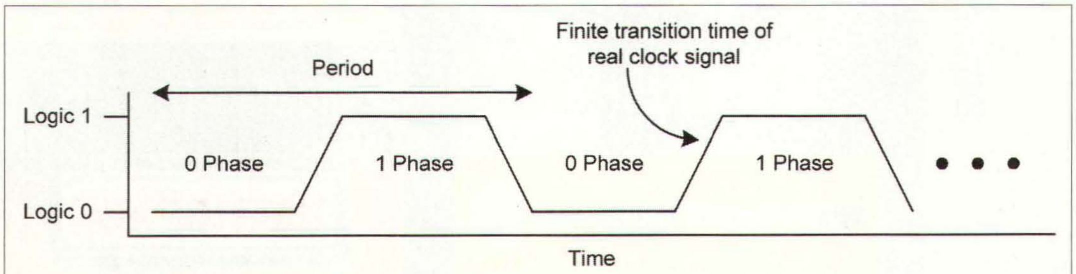


Figure 1: Digital Clock Signal

An ideal clock has a 50/50 duty-cycle, indicating that its period is divided evenly between the two states. Clocks regulate the operation of a digital system by allowing time for new results to be calculated by logic gates, and then capturing the results in flip-flops.

D Flip-Flops

There are several types of flip-flops, but the most common type in use today is the D flip-flop. Other types of flip-flops include RS and JK, but this discussion is restricted to D flip-flops because of their standardized usage. A D flip-flop is often called a flop for short and this terminology is used throughout this article. A basic rising-edge triggered flop has two inputs, and one output as shown in Figure 2a. By convention, the input to a flop is labeled D, the output is labeled Q, and the clock is represented graphically by a triangle.

When the clock transitions from 0 to 1, the state at the D input is propagated to the Q output and stored until the next rising edge. State-full logic is often described through the use of a timing diagram — a drawing of logic state versus time. Figure 2b shows a basic flop timing diagram where the clock's rising edge triggers a change in the flop's state. Prior to the rising edge, the flop has its initial state — Q_0 and an arbitrary 0 or 1 input is applied as D_0. The rising edge loads D_0 into the flop, which is reflected at the output. Once triggered, the flop's input can change without affecting the output until the next rising edge. Therefore, the input is labeled as "don't care," or "xxx" following the clock's rising edge.

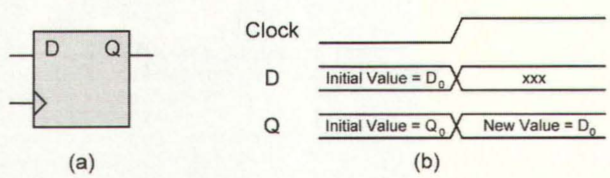


Figure 2: Rising-Edge Triggered Flop

Rising-edge flops are the norm, although some flops are falling-edge triggered. A falling-edge triggered flop is indicated by placing an inversion bubble at the clock input as done in Figure 3. Operation is the same with the exception that the polarity of the clock is inverted. The remainder of this discussion assumes rising-edge triggered flops, unless explicitly stated otherwise.

Flop Features

There are several common feature enhancements to the basic flop including clock-enable, set, and clear inputs and a complementary output. Clock enable is used as a triggering qualifier each time a rising clock edge is detected. The D input is only loaded if clock enable is set to its active state. Inputs in general are defined by device manufacturers to be either active-low or active-high. An active-low signal is effective when set to 0 and an active-high signal is effective when set to 1. Signals are assumed to be active-high unless otherwise indicated. Active-low inputs are commonly indicated by the same inversion bubble used to indicate a falling-edge clock. When a signal is driven to its active state, it is said to be asserted. A signal is de-asserted when driven to its inactive state.

Set and clear inputs explicitly force a flop to a 1 or 0 state, respectively. Such inputs are often used to initialize a digital system to a known state when it is first turned on. Otherwise, the flop powers-up in a random state, which can cause problems for certain logic. Set and clear inputs can be either synchronous or asynchronous. Synchronous inputs take effect only on the rising clock edge, while asynchronous inputs take effect immediately upon being asserted. A complementary output is simply an inverted copy of the main output.

A truth table for a flop enhanced with the features just discussed is shown in Table 1. The truth table assumes a synchronous, active-high clock enable (EN) and synchronous, active-low set and clear inputs. The rising edge of the clock is indicated by the ↑ symbol. When the clock is at either static value, the outputs of the flop remain in their existing states. When the clock rises, the D, EN, $\overline{CLR}$, $\overline{SET}$ and inputs are sampled and acted on accordingly. As a general rule, conflicting information such as asserting $\overline{CLR}$ and $\overline{SET}$ at the same time should be avoided because unknown results may arise. The exact behavior, in this case, depends on the specific flop implementation and may vary by manufacturer.

Ripple Counters

A basic application of flops is a binary ripple counter.

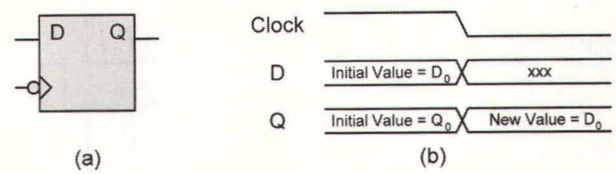


Figure 3: Falling-Edge Triggered Flop

Clock	D	EN	$\overline{CLR}$	$\overline{SET}$	Q	$\overline{Q}$
0	X	X	X	X	Q_{static}	$\overline{Q_{static}}$
↑	0	0	1	1	Q_{static}	$\overline{Q_{static}}$
↑	0	1	1	1	0	1
↑	1	1	1	1	1	0
↑	X	X	0	1	0	1
↑	X	X	1	0	1	0
↑	X	X	0	0	?	?
1	X	X	X	X	Q_{static}	$\overline{Q_{static}}$

Table 1: Enhanced Flop Truth Table

Multiple flops can be cascaded as shown in Figure 4 such that each complementary output is fed back to that flop's input and also used to clock the next flop.

The current count value is represented by the non-inverted flop outputs with the first flop representing the least-significant bit. A three-bit counter is shown with an active-low reset input so that the counter can be cleared to begin at zero.

The counter circuit diagram uses the standard convention of showing electrical connectivity between intersecting wires by means of a junction dot. Wires that cross without a dot at their intersection are not electrically connected.

The ripple counter's operation is illustrated in Figure 5. Each bit starts out at zero if $\overline{RESET}$ is asserted. Counting

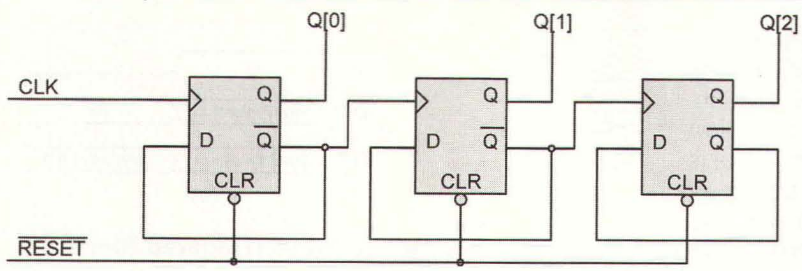


Figure 4: Three-Bit Ripple Counter

begins on the first rising edge of CLK following the de-assertion of $\overline{RESET}$. The least-significant bit, Q[0], increments from 0 to 1 because its D input is driven by the complementary output, which is 1.

The complementary output transitions to 0, which does not trigger the Q[1] rising-edge flop, but does set up the conditions for a trigger after the next CLK rising edge. When CLK rises again, Q[0] transitions back to 0 and $\overline{Q[0]}$ transitions to 1, forming a rising edge to trigger Q[1], which loads a 1. This sequence continues until the count

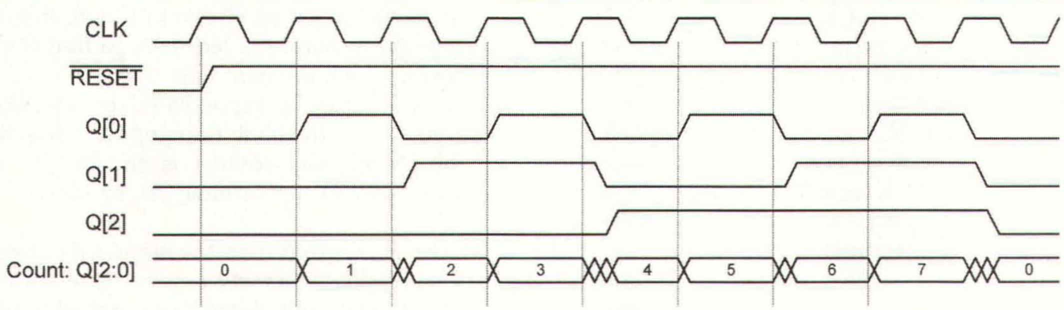


Figure 5: Ripple Counter Timing Diagram

value reaches seven, at which point the counter rolls over to zero and the sequence begins again. An undesirable characteristic of the ripple counter is that it takes longer for a new count value to stabilize as the number of bits in the counter increases. Because each flop's output clocks the next flop in the sequence, it can take some time for all flops to be updated following the CLK rising edge. Slow systems may not find this burdensome, but the added ripple delay is unacceptable in most high-speed applications.

Synchronous Logic

It has been shown that clock signals regulate the operation of a state-full digital system by causing new values to be loaded into flops on each active clock edge. Synchronous logic is the general term for a collection of logic gates and flops that are controlled by a common clock. The ripple counter is not synchronous, even though it's controlled by a clock, because each flop has its own clock, which leads to the undesirable ripple output characteristic previously mentioned.

A synchronous circuit has all of its flops transition at the same time so that they settle at the same time with a resultant improvement in performance. Another benefit of synchronous logic is easier circuit analysis because all flops change at the same time.

Synchronous Counters

Designing a synchronous counter requires the addition of logic to calculate the next count value based on the current count value. Figure 6 shows a high-level block diagram of a synchronous counter, and is also representative of synchronous logic in general. Synchronous circuits consist of state-full elements (flops), with combinatorial logic providing feedback to generate the next state based on the current state.

Combinatorial logic is the term used to describe logic gates that have no state on their own. Inputs flow directly through combinatorial logic to outputs, and must be captured by flops to preserve their state. An example of synchronous logic design can be made of converting the three-bit ripple counter into a synchronous equivalent. Counters are a common logic structure and they can be designed in a variety of ways.

The Boolean equations for small counters may be directly solved using a truth table. Larger counters may be assembled in regular structures using binary adders that generate the next count value by adding 1 to the current value. A three-bit counter is easily handled with a truth table methodology. The basic task is to create a truth table relating each possible current state to a next state as shown in Table 2.

Three Boolean equations are necessary — one for each bit that feeds back to the count state flops. If the flop inputs are labeled D[2:0], the outputs are labeled Q[2:0], and an active-high synchronous reset is defined, the following equations can be developed:

$$D[0] = \overline{Q[0]} \,\&\, \overline{RESET}$$

$$D[1] = ((\overline{Q[0]} \,\&\, Q[1]) + (Q[0] \,\&\, \overline{Q[1]})) \,\&\, \overline{RESET} = (Q[0] \oplus Q[1]) \,\&\, \overline{RESET}$$

$$D[2] = ((\overline{Q[2]} \,\&\, Q[1] \,\&\, Q[0]) + (Q[2] \,\&\, \overline{Q[1]}) + (Q[2] \,\&\, \overline{Q[0]})) \,\&\, \overline{RESET}$$

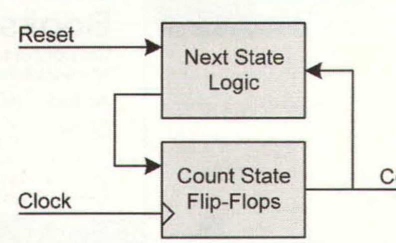


Figure 6: Synchronous Counter Block Diagram

Reset	Current State	Next State
1	XXX	000
0	000	001
0	001	010
0	010	011
0	011	100
0	100	101
0	101	110
0	110	111
0	111	000

Table 2: Three-Bit Counter Truth Table

Each equation's output is forced to 0 when RESET is asserted. Otherwise, the counter increments on each rising clock edge. Synchronous logic design allows any function to be implemented by changing the feedback logic. It would not be difficult to change the counter logic to count only odd or even numbers, or to count only as high as five before rolling over to zero. Unlike the ripple counter whose structure supports a fixed counting sequence, next-state logic can be defined arbitrarily according to an application's needs.

More than Counters

Once the basic scheme of designing next-state logic is understood, arbitrary logical sequences may be designed in hardware to form structures called finite state machines. While beyond the scope of this article, state machines are analogous to software programs and can be used to step through microprocessor bus transfers, communications protocols, or any hardware processing task.

Unlike simple counters, state machines incorporate external inputs into their next-state logic so that decisions can be made on which state should be selected. Branching and input/output decisions based on external signals allow the implementation of arbitrary algorithms and it is through such basic concepts that complex digital processing circuits may be designed. **NV**

A Quick Note on Symbology

Boolean equations are written with varying styles, each of which is valid so long as it remains consistent and conforms to algebraic rules. This article uses the following conventions. Inversion, or a NOT gate, is represented with a horizontal bar over the variable in question: $\overline{FOO}$. A product, or AND gate, is represented as: A & B . A sum, or OR gate, is represented as: A + B. An exclusive-OR is represented as: A ⊕ B. As always, parentheses explicitly indicate precedence in a mathematical equation. Vector notation is used to associate multiple individual signals when these signals are used together in a bus. Brackets are used to indicate a vector or bus: the four-bit vector, FOO[3:0], is capable of representing 2^4 or 16 unique values.

Mark holds a bachelor's degree in electrical engineering from The Cooper Union in New York City. He can be reached via email at **mark_balch@hotmail.com**

Exploring and Experimenting With Lasers and Their Properties

Laser Insight

Construction of the Cr:Ruby Laser Continues ...

The past few columns have been devoted to the building of a Cr:Ruby laser. Last month, we looked at the control and high voltage monitoring circuit and how it controls the supply under various operating system conditions. This month, we'll be looking at the high voltage stuff and lamp firing methods.

However, because this is a serious laser, I must be sure that I cover things thoroughly, and in tune with this, I must repeat the warning I gave earlier about it, and its safe use.

This article is the last part for this project, and is the final link before actually firing the laser. The schematic for the high voltage section of this laser is shown in Figure 30-1. This circuit is, again, quite straightforward and should not present any problems either in construction or in operation. There are really two parts to this schematic: the first part deals with the high voltage capacitor charging, and the second with the lamp trigger.

Some Notes on the Components

The transformer used to charge the main capacitor bank is a 1,500 VAC device used for small neon signs. I found mine at a surplus store here in Orlando, FL, but I have seen similar devices sold by many of the advertisers in this magazine, so look around. Since the duty cycle is low, the charge requirements are quite modest, and even a small transformer will work. My unit was rated at 30 mA maximum load, but anything from 15 mA and up would be okay. If the capacitor takes too long to charge, the dump solenoid may activate before the charge voltage reaches its set point. If this happens, you may need to adjust the timing resistor and/or capacitor in the 555 timer circuit.

The transformer for the trigger circuit is a small mains isolation transformer, with dual windings. The transformer I used has four independent sets of 110 VAC windings on it, so I series connected two of the windings to act as the output, and paralleled the other two for the input. Two series windings give about 240 VAC when used like this, and the output is rectified to boost up the DC voltage to 300 VDC, which is adequate for the trigger circuit.

The trigger transformer is quite easy, though I used an ignition coil from an old Ford pick-up truck, so if you have an old coil, give it a try. Otherwise, you can pick one up at a junkyard for a couple of dollars. Again, the duty cycle is so low on this laser that the momentary application of 300 VDC to the primary of this transformer will not do any damage. The pulse lasts for only about 2-3 microseconds.

The resistor (R1) in series with the diode bridge limits the inrush current to the capacitors, and protects the diodes and transformer from drawing too much current. When the capacitors are completely discharged, they look like a short circuit to a changing voltage (which happens when you press the CHARGE button). The diodes would see a large forward current if R1 was not there, leading to early failure. This resistor sees 2,000 volts (or more) when the system is operating, so here again, I suggest using a string of resistors to make R1. I used a series string of ten 4.7 K at 2 W resistors to make this unit, laying them out in a zigzag pattern on a piece of perfboard, and mounted this board to a plastic panel to give adequate isolation.

CAUTION

The laser to be described 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 charge or 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. 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 into 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!! Neither the author nor this magazine can be held responsible for your actions, so please be careful and act responsibly.

R4 is the DUMP resistor, and is wired in series with the contacts of the DUMP solenoid, as described in last month's column. One end of this resistor is soldered to the high voltage side of the capacitor bank as shown, and the other end connected to the stud on the dump solenoid.

When the dump solenoid is de-energized, the contacts close, discharging the main capacitors through R4. The resistor should be rated at about 50 W minimum, and must be mounted carefully to avoid arc over. This circuit has about a 0.75 second time constant (CR), and the capacitors should be almost completely drained after five CR periods (as a rule of thumb), so you should be safe in working on the system after about four seconds (unless the resistor goes open circuit!!!). But before working on the high voltage circuit, you are well advised to make sure the capacitors are fully discharged. Don't take any chances — this supply can kill!!

It may seem redundant to keep talking about safety issues, but it is absolutely essential to be sure of what you are doing, especially if you are working alone, or with a young audience.

K1 is a 110 VAC operated relay used to supply power to the high voltage circuit. It is energized when relay K2 (on the power distribution and interlock board) is energized. The reason I am using two relays here is that the small relays used on the interlock board do not have sufficient handling capabilities for the inductive loading of the transformers. The water pump is small, and has a much lower power requirement, so a small relay is okay there. These relay contacts should be rated for 10 A at 240 VAC.

Finally, R2 and R3 are permanently wired across the main capacitor bank to bleed off any residual charge from the capacitors. These are rated at 1 W, but I used two 2 W resistors in series for each component, not so much to lower the power dissipation, but to reduce the voltage stresses.

Construction Notes

Again, I leave the construction method up to you, using whatever you feel comfortable with. Bear in mind, though, the voltage levels being dealt with here. You could see 2,000 volts or more across the capacitor bank when fully charged; 2,000 volts across 150 µF equals 300 Joules. That much energy can cause a lot of damage if a short occurs, or if an arc jumps too short a gap between components.

Give yourself plenty of space between the high voltage components, and especially between the high voltage and low voltage parts. Use plastic insulation between the capacitors, so that the metal cans do not touch each other. Make sure your connections are both crimped and soldered.

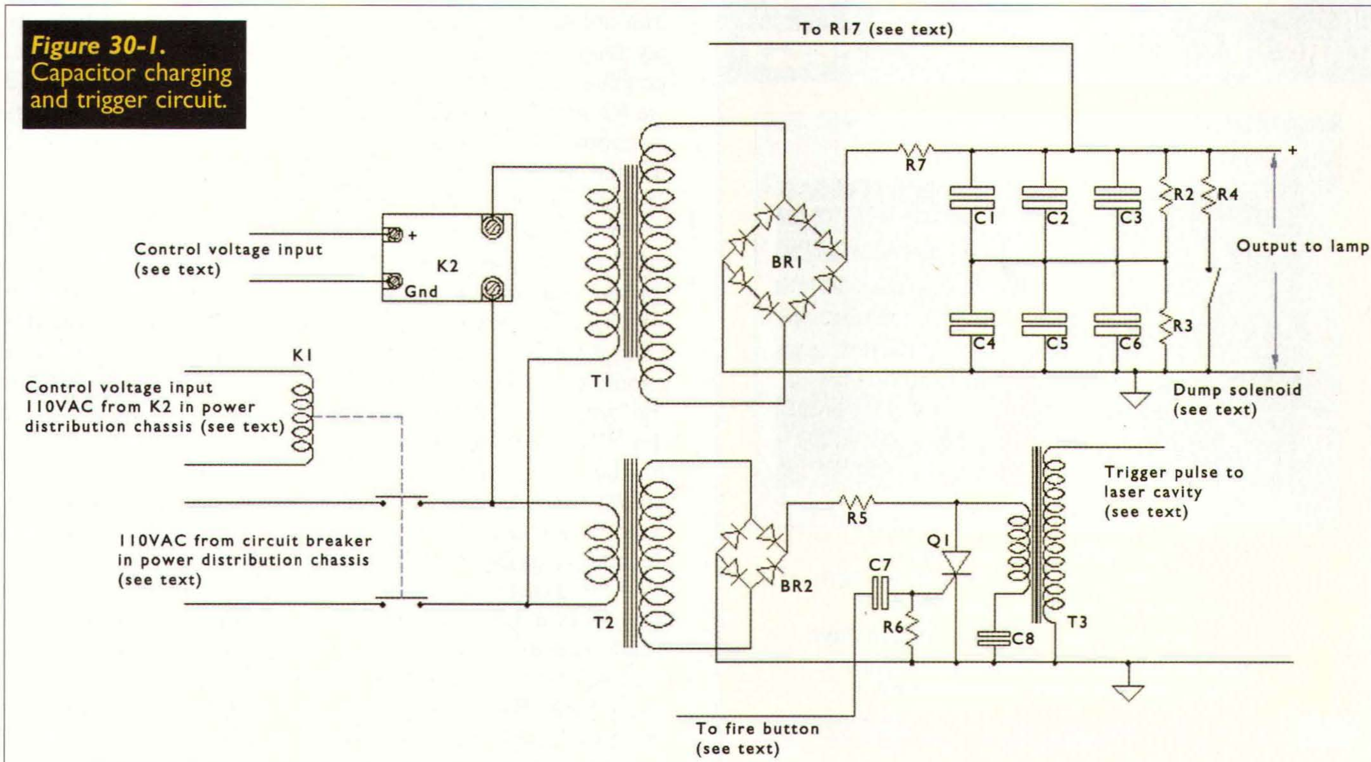
In my experience, a crimped joint will erode after a few hundred high-current pulses. A properly soldered joint is much better, but still degrades after several hundred more shots. My practice, for the last 20 years, has been to both crimp and then solder any high voltage/high current connection, where practical.

Theory of Operation

Let's assume the start-up sequence proceeds normally up to the time to charge the capacitors. When the high voltage is turned on, power is supplied to the trigger transformer circuit, and the high voltage capacitor circuit via K1. The trigger circuit provides the high voltage pulse necessary to breakdown the gas in the flashlamp, so that the charge in the main capacitor bank can produce the optical energy needed to pump the laser rod. The trigger circuit begins to charge C8 when turned on, and remains on as long as the high voltage relay K1 is energized.

When capacitor C8 is fully charged, it reaches a maximum of about 320 VDC. Pressing the FIRE button delivers a 12 V pulse into the gate of Q1, triggering the SCR into conduction. Thus triggered, the charge on C8

Figure 30-1. Capacitor charging and trigger circuit.



HV Cap Selection

For initial testing, use a low value capacitor (1-2mF 1,000V) for C1-C6 (see main article text).

C1-C6 are high discharge current capacitors specifically designed for this application. Do not try to use other types.

Unsuitable capacitors will not be able to withstand repeated high current discharges, and may fail catastrophically. Suitable capacitors are available from Maxwell Labs (CA), Aerovox (MA), Condenser Products (FL), Plastic Capacitors (IL), and a few other companies. Type in "laser capacitors" in your favorite search engine for current URLs.

pulses the primary of T3, which then puts out a very high voltage pulse to trigger the lamp. Because of the low pressure nature of the lamp, it is only necessary to introduce a high voltage field in the vicinity of the lamp to initiate the plasma stream. The main discharge capacitors are connected across the lamp, and once the stream is started, the main discharge can proceed. This all happens in a few tens of microseconds. However, the high voltage capacitors are not charged at this point, so read further.

The power for the capacitor charging circuit is further controlled by the solid state relay Q2. When the CHARGE button is pressed, this relay is turned on, and the capacitors begin to charge via the diode bridge and R1. The time constant here is about seven seconds, and using the "times five" rule of thumb, you get a maximum charge time of about 35 seconds for a full charge. Again, if this time is too slow, the DUMP solenoid will terminate the charge before reaching the set voltage, and you'll have to adjust the 555 timer to allow full charge to be reached, plus a few seconds to allow you to fire the laser.

Please be very careful when adjusting anything in the power supply. It is very dangerous and all safety precautions should be observed. Always short out the main capacitor bank before touching anything in the high voltage chassis, and don't forget the small capacitors either. C8 can pack a pretty powerful wallop!

Initial Testing and Calibration

For the initial tests, do not use the 100 µF capacitors in the main bank. Instead, get a couple of 1-2 µF caps of adequate voltage rating. If there is a potential problem with the charging or discharging, the available energy for damage will be much less. Connect everything to the laser head, observing the lamp polarity.

If the control and high voltage monitoring board you made last month works properly, you can hook it up to this circuit using the small caps as described above. With small caps in place, the charge time is going to be very short, so be prepared!

For the initial tests, disconnect the 110 VAC wires from the solid state relay. This way, you can check the operation of the trigger circuit without having to worry about the high voltage caps just yet. If you have an oscilloscope, connect the leads across the SCR, and set the amplitude to about 10 V/div. Set the timebase to trigger on a negative slope, and put the trace on a convenient level. Get a DC power supply that delivers s about 20-30 volts or so, and connect the supply lines to across the diode bridge — negative to negative, positive to positive. The low voltage will charge capacitor C8 via R5 and T3 primary. Take a jumper wire and momentarily connect C7 (pushbutton side) to +12 VDC. This should trigger the SCR into conduction, shorting the top of T3 (effectively) to the bottom side of C8.

You should see the oscilloscope trigger when the SCR conducts. This puts a high current pulse through the transformer, resulting in a high voltage pulse from the secondary winding. This high voltage pulse is used to initiate the discharge through the lamp. If this test works okay, then you should now repeat it using the high voltage. When you turn the system on, if everything is working correctly, pressing the HV ON button will apply 120 VAC to the primary of T2 on this chassis. This means there will be about 300 VDC across C8, so please be careful. Adjust the oscilloscope as needed, and watch out for the high voltage pulse from the secondary of the trigger transformer.

The trigger voltage must be applied to one of the reflector halves in the laser head. This is best done by drilling a small hole in one corner of a reflector and threading a thin stainless steel wire through, twisting it around to make a firm connection. Bring the wire through the head block by passing it under the "O" ring. A better way to do this is to drill a small hole through the side of the head block, and put a stainless steel screw through, connecting the wire on the inside. Then the high voltage connection can be made on the outside of the block, to the other end of the screw.

Shut the system down and reconnect the 110 AC voltage to the solid state relay. Make sure the PFN voltage control is turned down to minimum and restart the system. Monitor the high voltage caps using a high voltage probe on a multimeter or an oscilloscope.

When the high voltage is first turned on, there may be some gradual creep in the DC voltage on the capacitors. Slowly turn up the PFN voltage control, and you should hear occasional 'thumps' from T1, indicating that charge is being applied to the caps, but because of their small size (you did put the small caps in, right?), the solid state relay shuts off almost immediately (see, I told you it would be fast charging).

Continue turning up the PFN voltage to about 200 volts. Compare the reading on the multimeter or oscilloscope with the reading on the PFN voltmeter on the front panel. Trim VR3 on the control board so that the readings match. You may need to check this again at a higher level, but for now, we'll leave it where it is. At 200 volts on the main caps, there will be no laser action, but the lamp may flash. Place a piece of white card close to the end of the laser head, and look for a brief flash when you press the FIRE button.

Resist the temptation to look down the rod, even if you leave out the mirrors. The light from the lamp is very bright, and you will see it on the card. If it flashes, then all is well. If it does not flash, try increasing the PFN voltage more, but don't go over 500 volts at this time. If you don't see a flash, there may be a wiring error or perhaps something is shorting the high voltage pulse to ground.

One thing you must be aware of is the water circulating around the head. If the water is not distilled or de-ionized, then the conductivity may be enough to swamp out the HV pulse from the trigger transformer, in which case you will not get the initializing pulse down the lamp, but rather, through the water. If you installed the DI filter as described in a previous article, then simply leave the water running without the HV on for about an hour or so to clean it up. Then try again. Continue running the system at higher PFN voltage levels, monitoring the voltage reading on the panel meter.

If everything appears to be working properly, turn the system off, and install the main capacitor bank. Until you get a better feel for what the laser can do, I suggest installing the capacitors two at a time (series connected of course). This allows you to gradually build up the stored energy of the system while minimizing the possibility of damage.

Whew, this has been a long project! I hope you have as much success in building your laser as I have. You can now go ahead and start to experiment, drilling holes or welding thin metals. With some additional components, you can also use this laser for holography, as I mentioned previously, and we'll take a look at some of the other stuff you'll need to make double pulsed holograms in the next issue. We'll also be looking at ways we can quantify the output of this laser in terms of energy and beam quality.

If you have questions about this column, or ideas for future columns, you may contact me as always at: **stanley_york@peoplepc.com** or through this magazine. NV

Parts List

T1	1,500 VAC neon sign transformer (see text)
T2	110/220 VAC isolation transformer — Newark #VPS230-110
T3	Automobile ignition coil (see text)
K1	120/240 VAC 10A mains contactor — Digi-Key #PB519-ND
K2	Solid state relay — Digi-Key #CC1162-ND
R1	47K 20W (see text)
R2,R3	1M (see text)
R4	5K 50W (see text)
R5	10K 2W
R6	4.7K 1/2W
C1-C6	100µF 1,000 VDC (see text)
C7	0.1µF 50V
C8	1.0µF 350VDC
BR1	Diode bridge 5,000 PIV 0.25A (see text)
BR2	Diode bridge 600 PIV 1A
Q1	SCR 600V 50A Digi-Key #50RIA60-ND

by Jon Williams

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

Stamp Applications

Stamping on Down the Road

Summertime is vacation time, and I — like so many others around the world — hit the road for a few days out of the office for some fun and relaxation. The thing is, my job isn't usually very stressful (sometimes magazine deadlines can be tough ...) so I rarely feel like I need a vacation. That said, it's still nice to take a vacation every once in a while, especially when I can see friends and family that don't live near me here in Dallas, TX.

This year, I decided to pack up the SUV and drive to my brother's house in Columbus, OH. And, as I often do, I made it a working vacation by taking a bunch of Stamp goodies to work with while I was away from my office. One of my projects actually helped me drive door-to-door to my brother's house without hiccups. If you're guessing we're going to work with GPS again, you guessed correctly.

The reason for my renewed interest in GPS has more to do with my boss than me. You see, my boss, Ken, is the commander of the Parallax model air force. If you ever visit our facility in California, you'll find several gas-powered model airplanes in our warehouse. When the weather is good (a frequent occurrence in northern California), a small group of Parallax flyers will head to the local model airport and fly planes.

Of course, many of the Parallax planes are equipped with BASIC Stamp projects. Ken created a little flight recovery system using the Stamp and an accelerometer. One of our senior engineers, John, created a dual-engine synchronizer for one of his big airplanes. So where do I fit in? Well, Ken wanted to track his plane's flight path and speed, and asked me to come up with a method of doing it. The solution was to strap a small GPS receiver (Garmin eTrex) onto the plane with a BS2p acting as a data logger. I wrote about the methods used in our airplane data logger back in March of 2002.

The program has served us well, but Ken has been asking for better resolution in the data. You see, the old program uses standard NMEA 0183 strings from the GPS receiver that are spit out at 4,800 baud. With the bulk of information dumped by the receiver at this baud rate, we only get updates every two seconds. For a model airplane traveling around 80 MPH, this isn't great. What to do?

While reviewing the eTrex manual, I found that it has a simple text output method that can be set to 9,600 baud. This is a good start as it doubles the communication speed. The other nice thing about this method is that it uses fixed-position fields.

This will help make parsing data easier as we know exactly where everything is within the string. When using the $GPMRC string, some fields are variable-width which complicates the location of data.

Building a Digital Dash

Before tackling Ken's airplane code, I decided to experiment with the Garmin text output by creating a supplementary digital dash for my SUV. This would give me the opportunity to work with the text output in a useful manner — and help me get to my brother's house without having to call for directions.

The specs, then, for my digital dash are to display speed (in MPH), current time, direction of travel (in degrees), direction as a compass point (i.e., NW), and current segment distance (a secondary trip odometer). This all sounds very simple — until you look at the output from the Garmin GPS receiver when set to simple text output.

Simple Text — Not So Simple

For the benefits of speed when using the simple text output, we're strapped with a couple of tricky conversions to display the data as required for my digital dash project. The simple text output looks like this:

@020202183142N3251129W09701159G008+00165E000
0N0000D0001

For details on all the field positions, please have a look at this URL:

www.garmin.com/support/text_out.html

Here's the tricky bit: speed and direction — both very important to my project — are not directly available. This information is actually derived from two component vectors. The first vector represents North/South speed in meters-per-second; the second represents East/West speed in meters-per-second.

If it sounds like a bit of trigonometry is going to be required ... you got it.

Hey, Look What I Found!

An interesting thing happened when our compiler engineer, Jeff, ported the BASIC Stamp tokenizer from assembly language (not written by him) to C so that it could be compiled for other operating systems ... he found two previously-undocumented functions: **ATN** and **HYP**.

The first function, **ATN** (arctangent), returns the angle, in brads, to the vector represented by X and Y. Wow, that was a mouthful, so let's go through it. Take a look at Figure 1 — a PBASIC unit circle. The difference between a PBASIC unit circle and what we'd use in our trig class is that it is divided into 256 units instead of the 360 units we're accustomed to. These units are called binary radians, or brads. Each brad is about 1.4 degrees. When expressing the vector, X and Y are limited to values between -127 and 127 (signed bytes).

The other newly-found function is **HYP**. As you'd expect, this function returns the hypotenuse of a right-triangle with the sides represented by X and Y. And, like **ATN**, the X and Y values for **HYP** must be limited to -127 to 127.

Okay, then, let's get to it.

Code for the Road

Something that new programmers frequently run up against is the frightening feeling that their goals are greater than their programming skills. We've all been there — don't sweat it if you're in that state now. An easy way to overcome this fear is to write an outline program, then flesh it out as you go. The reason for this is that it gets you going, and frees you from the details that you will ultimately work out later.

Let me show you a real example. After thinking about my digital dash program, I wrote this chuck of code and it stuck:

```
Main:
  DO
    SERIN GPS,N9600,3750,No_GPS,[WAIT("@"),SPSTR 50]
    GOSUB Parse_GPS
    GOSUB Calc_Speed
    GOSUB Show_Speed
    GOSUB Show_Time
    GOSUB Show_Vector
    GOSUB Show_Compass
    GOSUB Show_Miles_Acc
  LOOP
```

There's only one "real" line of code (**SERIN**), and that wasn't a problem since I lifted it from a previous GPS program. The rest are calls to subroutines.

The next step, of course, is to create empty subroutines (just a label and **RETURN**) so that the program will compile without problems. Nothing will happen, except that we'll know we have a structure that works. After that, we flesh out each subroutine — testing as we go — until the program is complete.

Let's have a look at the **SERIN** line, since it does quite a bit of work. The first thing to note is that it will timeout if no data is received within 1.5 seconds (the 3,750 parameter corresponds to the timeout units on the BS2p, which are 400 microseconds). Assuming a signal does show up, the function will wait for the "@" character which is the string header.

Once it arrives, the next 50 characters will be buffered into the BS2p's scratchpad RAM so we can deal with them later.

The next step is to pull the extract we're interested in. This is done with the Parse_GPS subroutine. Here's a section of that code:

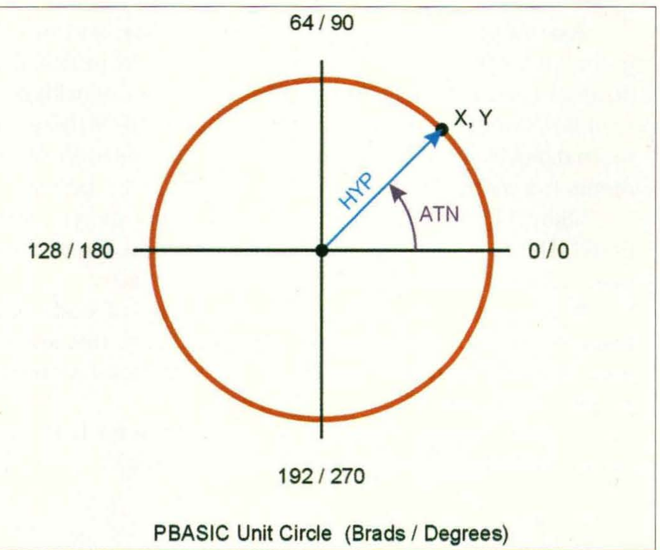


Figure 1.
PBASIC Unit Circle (Brads / Degrees)

```
Parse_GPS:
  idx = 6 : fldWidth = 2
  GOSUB Parse_Field
  hr = workVal + UtcAdj // 24
```

You'll see when you download the full listing that Parse_GPS routine is filled with calls like this. The purpose is to send the proper control values to Parse_Field and then store what gets returned in *workVal* in the target variable.

The variable *idx* is used to point to the start of a field, and *fldWidth* defines how wide that field is. After returning from Parse_Field, *workVal* holds the field value.

The hours field in the GPS string starts at position six and is two characters wide. The value returned will actually be UTC time (AKA Greenwich Mean Time) — not Central Daylight Time as I needed. The constant UtcAdj allows us to adjust for the difference between our local position and GMT. The real work, of course, takes place in the Parse_Field subroutine. Let's have a look:

```
Parse_Field:
  workVal = 0
  IF (fldWidth < 6) THEN
    DO WHILE (fldWidth > 0)
      workVal = workVal * 10
      GET idx, char
      workVal = workVal + (char - "0")
      fldWidth = fldWidth - 1
      idx = idx + 1
    LOOP
  ENDIF
  RETURN
```

On entering Parse_Field, the variable *workVal* gets cleared. The reason for this is that zero will be returned if a bad field width is passed to it. This seems like a better choice than returning the value from the last legal field access.

Assuming the field width is between one and five, it grabs a character from the string, converts it from ASCII to decimal, then shifts it left (remember, we're dealing with decimal numbers so a left-shift is a multiply by 10) if there are more digits in the string. Each pass through the loop decrements the width value and updates the character pointer.

Okay, I know what you're thinking: "Why did you shift first?" The reason is that it simplifies the code. On the first pass, no harm is done because *workVal* is zero.

If we waited, we'd have to insert a line of code that tests *fldWidth* for zero before shifting. I know this seems a bit odd, but once you run it through your head a couple times it will make sense.

To help out, let's look at a three character field that holds "123" and run through the value of *workVal*:

```
  0 - entry
  1 - first pass; fldWidth = 2
 12 - second pass; fldWidth = 1
123 - third pass; fldWidth = 0 (loop terminates)
```

Now that we have our numbers, it's time to crunch them and put them onto an LCD. The first calculated value is the trickiest: speed in miles per hour.

As I told you earlier, speed is derived from two vectors: North/South speed in meters-per-second, and East/West speed in meters-per-second. The **HYP** function is perfect for this — with one caveat. Since the limit for **HYP** is 127, we may have to scale the vectors before using the function. The reason for scaling is that 12.7 meters per second is about 28 miles per hour — and I was certainly planning to drive faster than that on my way to Ohio (otherwise it would have been a very long trip ...).

```
Calc_Speed:
  IF (velEW > velNS) THEN
    workVal = velEW
  ELSE
    workVal = velNS
  ENDIF

  LOOKDOWN workVal, <[128,255,382,509], workVal
  workVal = workVal + 1
  velEW = velEW / workVal
  velNS = velNS / workVal
  speed = velEW HYP velNS
  speed = speed * (workVal * 10) ** 14660 + 5 / 10

  mtr10 = mtr10 + ((velEW HYP velNS) * workVal)
  RETURN
```

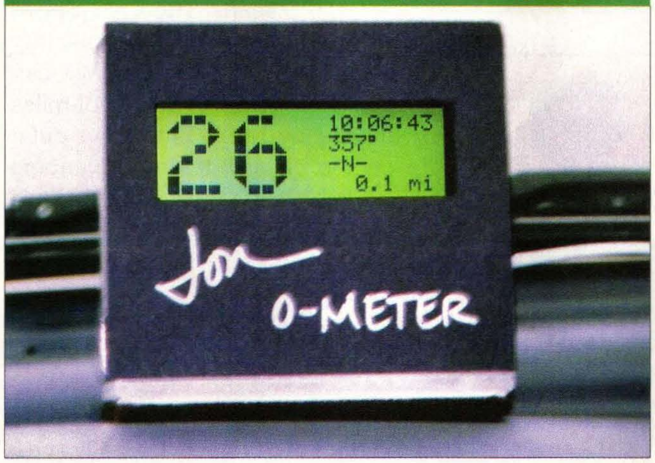
The Calc_Speed subroutine starts by finding the larger of the two speed vectors. This value is used in a **LOOKDOWN** table to create a scaling factor (1 to 4). Each vector is divided by the scaling factor and the speed is calculated with **HYP**. The next step involves a bit more math than we're used to. We have to scale the speed back up and convert to miles per hour. Notice that all the elements are scaled by 10 so that we can add five and divide by 10 to round up. Remember that we can multiply by fractional values with the ** operator. The term for **, in this case, is 14,660 — the same as multiplying by 0.2236 (the conversion factor for going from 0.1 MPS to 1 MPH).

Before we finish this routine, there is one last bit. Part of the project is to accumulate segment distance, and that's done in *mtr10* (0.1 meters). This is actually quite simple since the speed vectors are returned in tenths of a meter per second. Since we update once per second, we simply need to add our speed value to the accumulator. We'll convert it to tenths of miles later.

Displaying speed is so trivial that I'm not going to go through it. Why so easy? Because my old pal, Scott Edwards, thoughtfully added a "big characters" function to his 4-line LCD controllers. You can see how this looks in Figure 2, which shows the project in use.

Now that we know how fast we're going, it would be nice to know the direction we're headed. This information, like speed, is derived from the two direction vectors. This time we'll use the **ATN** function. Keep in mind that **ATN** returns brads, not degrees, so we'll have to convert. And

Figure 2. PBASIC Unit Circle (Brads / Degrees)



there's another thing to deal with. Take a look again at Figure 1. Notice how brads and degrees in the polar coordinate system start at the three o'clock position and increase as we rotate counter-clockwise. Now look at a standard magnetic compass. Notice how zero degrees is at the 12 o'clock position and increase while rotating in the clockwise direction. We'll have to deal with this. Don't worry though, it's not difficult. The code that handles this is the Show_Vector subroutine:

```
Show_Vector:
  IF (speed > 0) THEN
    GET 39, char
    IF (char = "W") THEN velEW = -velEW
    GET 44, char
    IF (char = "S") THEN velNS = -velNS
    vector = velEW ATN velNS
    vector = vector */ 360
    vector = 360 - vector + 90 // 360

    SEROUT LCD, N9600, [PosCmd, 35 + 64, RtAlign,
                        "3", DEC vector,
                        PosCmd, 35 + 64, DegSym]
  ELSE
    SEROUT LCD, N9600, [PosCmd, 32 + 64, "---"]
  ENDIF
  RETURN
```

All you math wizards recognize that the **ATN** function actually converts Cartesian coordinates to a polar (rotational) value. One adjustment that may be required to the vectors is to place them in the proper quadrants so that we get the correct angle from **ATN**. If we overlay a compass onto a Cartesian graph, we'll see that the south and west sides of the compass bearings fall into negative graph values. The Garmin GPS doesn't tell us this — it simply tells us North or South, East or West. So we do a quick check. If the North/South vector is south, we take the negative value of the speed vector; we do the same for the East/West vector.

Again, the **ATN** function returns brads. To convert to degrees, we will multiply by 1.4 (*/ 360). Finally, we have to reverse the direction by subtracting our direction from 360, then adding 90 degrees to reorient zero to the correct (12 o'clock) position.

Notice that we don't actually go through this trouble if we're not moving. You see, we can't tell which direction we're pointed unless the GPS receiver is moving. If we pass zero speed vectors to this routine, it will tell us we're pointed East (90 degrees). This will usually not be the case so we'll simply display dashes when the vehicle is stopped.

You may be wondering why we didn't scale the vector values when we calculated the speed. The reason is that the vectors were scaled by the Calc_Speed subroutine and not modified after — so they are already scaled appropriately for the **ATN** function.

The next step in the program is to convert the direction of travel to a more useful string; "-N-" when we're traveling on a heading of zero degrees, for example. The subroutine that handles this is called Show_Compass:

```
Show_Compass:
  SEROUT LCD, N9600, [PosCmd, 52 + 64]
  IF (speed > 0) THEN
    eePntr = vector * 100 + 1125 / 2250 // 16
    eePntr = eePntr * 3
    FOR idx = 0 TO 2
      READ eePntr + idx, char
      SEROUT LCD, N9600, [char]
    NEXT
  ELSE
    SEROUT LCD, N9600, ["---"]
  ENDIF
  RETURN
```

As with direction in degrees, we'll only show this value if moving. What this routine does is create a pointer to one of 16 strings. If we divide the compass face of 360 degrees by 16, we get 22.5. Since we want our pointer to be right in the middle of a 22.5 degree segment, we divide the segment width by two to get 11.25. The BASIC Stamp doesn't do floating point, so we multiply everything by 100 before doing the pointer math.

A simple loop handles pulling the string from a **DATA** table and printing it on the LCD. This is actually quite useful. While driving to my brother's house, I was watching the display to make sure that I was generally traveling in a north-easterly direction while driving. That was actually quite comforting across some very long, flat stretches of road.

We're almost there. The last thing to discuss is the trip meter built into the code. What I did before leaving home was go to one of the many Internet mapping sites and downloaded door-to-door directions to my brother's house. The directions basically told me to get on a specific road and travel a given distance. As you'll see in Figure 3, I've got a button on P0 so that I can reset the meter. What I did while driving was get on a road, press the segment reset button, then watch for it to increment to the distance given in my directions. Since the display was sitting on the dash-

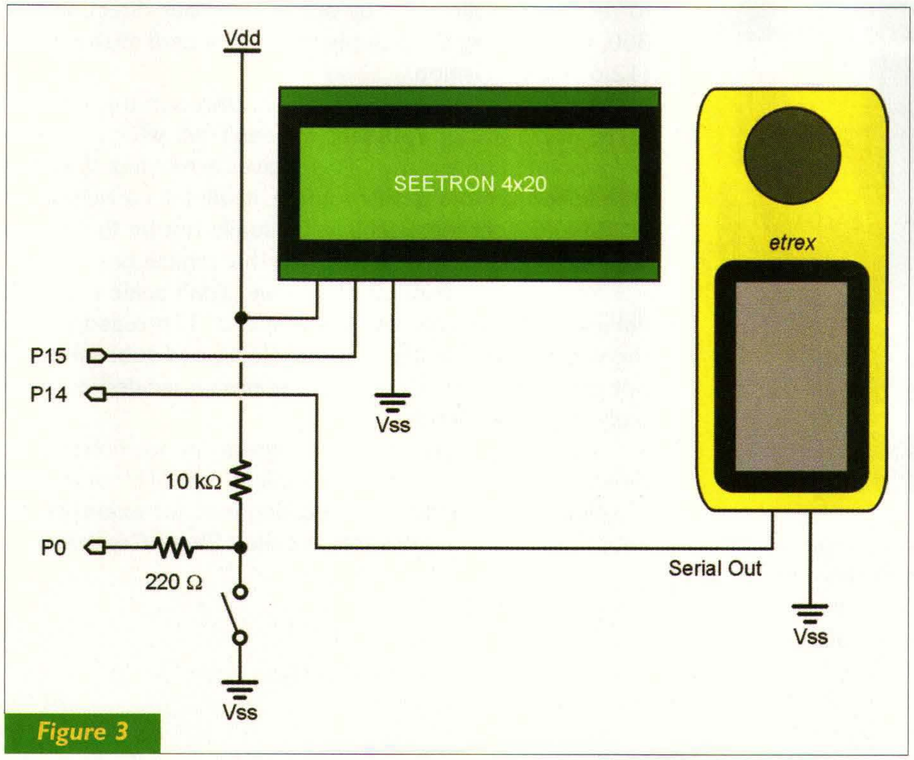


Figure 3

board right above the steering wheel, it was very easy to see and monitor. Without fail, every new junction was within a tenth of a mile of where it should have been.

Let's have a look at the segment code.

```
Show_Miles_Acc:
  IF (FuncBtn = Pressed) THEN
    mtr10 = 0
    mi10 = 0
  ENDIF

  IF (mtr10 >= 1609) THEN
    mi10 = mi10 + 1 // 10000
    mtr10 = mtr10 - 1609
  ENDIF

  SEROUT LCD, N9600, [PosCmd, 75 + 64,
                      RtAlign, "3",
                      DEC (mi10 / 10),
                      PosCmd, 75 + 64, ".",
                      DEC1 mi10, " mi"]
  RETURN
```

On entering this subroutine, we check to see if the button is being pressed. If it is, we clear the segment accumulators. Keep in mind that this routine — like all routines — only gets called once per second, so you may need to hold the button for a moment. Most of the time the button will not be pressed. In this case we'll look at the tenths-of-meters accumulator and compare it to 1,609 (the conversion factor to go from tenths-of-meters to tenths-of-miles).

Let me go back and review some logic. The speed output values in the GPS string are in tenths-of-meters per second. Since we're checking every second, the speed value becomes our distance traveled between GPS scans. The Calc_Speed subroutine took care of accumulating distance in tenths-of-meters. We can convert this value to tenths-of-miles by dividing by 1,609. Finally, we put it up on the display, taking advantage of another nice feature or SEETRON displays: the ability to right-justify numbers.

The Need for Speed Monitoring

This code was a bit more complicated than the projects I usually present here, but I think it was fun and was certainly a good learning experience for me. Be sure to download the full listing and go through it slowly — it should all make sense once you've studied it for a while.

The cool thing about this project is that it provides non-contact speed and distance monitoring. Since it uses GPS, it can be put on anything that moves — a car, boat, scooter, or go-kart. Do you want to know how fast your soapbox derby car goes? Now you can.

Before I sign off this month, let me give you one more web link. While working on this program, I found the following conversion site to be useful:

www.sciencemadesimple.com/conversions.html

Stamps in the Shack!

Finally, for those of you who read this column but haven't actually started with Stamps, or those of you who might want to get a friend or youngster started ... good news. Parallax has teamed with RadioShack to put a great starter kit in select RadioShack stores (those in major population centers). The kit includes the Parallax HomeWork board and the "What's a Microcontroller?" text and components. It's a great way to get started and at a fantastic price — and you can pick it up at your local RadioShack. Look for the starter kits to hit the shelves this holiday season.

That's all for now. Happy Thanksgiving to you and yours ... and as always, Happy Stamping. **NV**

Resources

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

The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Test Equipment

Test equipment is probably the most important investment for a start-up company (or hobbyist). Choosing the right equipment saves time and money. Knowing how to get the most out of your equipment is critical, too. In last April's column, *A Primer on Testing*, I discussed philosophy and theory. Today, we'll look at the practical side of your test bench.

Why Testing is Important

Testing demonstrates how something works — or doesn't. It *teaches* you. If you measure the input of an amplifier and see 0.1 volts and the output is 10 volts, you learn that the amplifier has a gain of 100. If you see a glitch when a circuit fails, you learn that the glitch is the problem. Testing lets you explore a circuit. Most students and engineers enjoy probing a new piece of gear to see what it does.

Testing also collects data. There is the obvious need for this to determine if something is operating properly. However, there is another important and subtle aspect to this. Understanding how test instruments work allows you to understand instrumentation. Instrumentation is fundamental to signal analysis. And signal analysis is used in nearly every electronic device.

Every microcomputer with an analog to digital converter (A/D) is a simple test instrument. Every switch closure causes a voltage to change. Every data cable carries a signal that must be processed. It's hard to think of any electronic product that does not test something in some way. So, you can see why testing and the understanding of testing fundamentals is so important at both a practical and a theoretical level.

New or Used

The general topic of used equipment needs to be discussed before delving into specific requirements. Obviously, used equipment is much less expensive than new. And "used" doesn't mean "used up." It's quite clear that good, used equipment is available. The question is how to determine what is "good" and what is not.

Generally, I always look to the used market before buying any major piece of test gear. However, there are a few exceptions to this. Used digital (logic analyzers, etc.) and computerized equipment is often available new for comparable prices. Also, used mechanical tools and equipment can simply wear out and be very difficult to repair.

There is also one very important rule to buying previously owned gear. If you don't know exactly what you are buying — don't buy it. There are many products that have similar part numbers that are quite different in performance. There are often "A" versions, "B" versions, and so forth. Additionally, some oscilloscopes need "plug-in" sub-assemblies and are not functional without them. Obviously, this can come as a big surprise, if you don't know exactly what you are buying. A 10 or 15 year old catalog is extremely useful here.

Another point to remember is that buying a name brand piece of used gear will often outlast a new piece of off-brand gear. This is because name brands (Tektronix, Hewlett/Packard, and Fluke) are designed for professional use and tend to age well. They also have a large user base, so special parts are relatively easy to get. Off-brands (Heath, RadioShack, and Eico) are usually built for the hobbyist. They are fine for that purpose. However, in a business setting (or serious amateur), these are simply not reliable enough. This is why used-equipment companies don't carry off-brands.

Finally, *always* get a service/operator's manual when you buy the equipment. Often the seller can provide you with one. If not, then go to the manufacturer or try third-party documentation vendors like Sam's Photofacts. It's hard to repair, calibrate, or use equipment without a service manual. If you don't get one when you are thinking about it, you won't have one when you really need one. What's more, as time passes, manuals are harder to get. The value of a service manual is considerable.

There are several classes of used equipment dealers. I've made up my own names for them: salvagers, re-sellers, calibrators, and leasers. Let's look briefly at each class.

Salvagers are companies that buy equipment literally by the ton. They may have no background in electronics. To them, an oscilloscope works if you turn it on and a trace is seen. Usually, the equipment is quite old and no warranty is available. The prices are great ... often a few pennies on the dollar. But, the risk is also great. Usually all sales are final. This is a gambler's market. If an individual is selling an item on the web, it should probably be considered in this class.

Re-sellers are a step-up from the

salvagers. They understand test equipment better. They also know how to perform basic tests to see if a unit is functional. They usually warrant functionality but not performance. For example, this means that the oscilloscope works reasonably well, but the time-base may be off slightly.

Companies selling surplus equipment on the web usually fall into this class. Prices can be 10% to 25% of the original price. Usually there is a warranty for functionality and some type of basic return policy (perhaps 30 days). This choice may be acceptable for a hobbyist, but not for a business. The equipment is still not reliable enough for that.

Calibrators sell equipment that is guaranteed to meet original factory specifications. This means that it operates as if it was new. The prices are slightly higher than the re-sellers, but this class of equipment is suitable for any purpose. Individuals and companies selling surplus equipment do *not* fall into this class. This means anything on eBay is probably *not* in this class, either. Only companies that specialize in selling calibrated, used equipment fall into this class. Look for the "Fully calibrated to factory specifications" phrase. If it doesn't specifically say it's fully calibrated, it probably isn't. These companies provide a warranty for performance and a return policy. This is a good choice for older equipment (5 to 10 years old or more).

Leasers are companies that buy new equipment and lease it out. After a couple of years, they have recouped their investment and made a profit. So, they then sell off the equipment for cash. This equipment is newer than the calibrators. In fact, it may still be under the original factory warranty. The equipment is generally calibrated. At the worst, you can pay a nominal fee for calibration. Prices are usually 70% to 90% of the original price. But, if you need a $20,000.00 spectrum analyzer and only have $15,000.00, this is the class to examine. This class is suitable for any purpose, as well.

The Basics

A good power supply is more important than most people realize. Poor regulation can lead to noise and all sorts of strange problems. A good, current-limited, adjustable, linear supply is ideal. Switching regulators are electrically noisy and really only acceptable for digital circuits. (And sometimes not even then.) Current limiting is important because it often stops parts from failing (exploding, burning up, etc.) when there is a short circuit.

Simple homemade circuits using the standard three terminal regulators are fine for the hobbyist. They inherently limit the current to about an amp or so. And there are ways to current limit these, as well. (See the manufacturers' application notes for details. Or, if there's a big demand, I'll provide the design I use.) For business, a good bench supply is necessary.

Note there is nothing wrong with using batteries as a power supply as long as they are fresh enough. (Weak batteries can also create strange problems.) Batteries are inherently quiet and have limited current. I often use standard nine volt batteries when breadboarding circuits. However, they are very expensive in the long run.

You will also have to have a multimeter or two (I think I've got about six). You can usually get by with a good digital one (3.5 digits for hobby and 4.5 digits or more for serious work) and a cheap analog one. The digital one is for precision measurements that no analog meter can match. The analog meter is very useful for showing slow variations or averaging out unusual wave-shapes.

Modern DMMs (Digital Multi-Meters) have all sorts of capabilities that were unheard of 10 years ago. Sometimes, paying a little extra for a special function in a meter can save paying for a separate instrument (like measuring capacitance). Look closely at what's available. There's a huge variety out there. Note, always look at the DC input resistance (sometimes called "input impedance" and not to be confused with resistance ranges). It should be as high as possible. Preferably at least 10 megohms. (My 5.5 digit Fluke meter's resistance is greater than 1,000 megohms.)

The last basic bench test instrument is an oscilloscope. You cannot do any serious design work without one. Yes, it's expensive, but it's necessary. You wouldn't try to solder with a match would you? It's probably best to start out with a plain analog one (unless you have specific requirements that demand a digital one). As it stands now, you can get the best bandwidth for the buck with analog. However, this may not be true in the future. You can get good used analog 'scopes at very good prices.

The bandwidth is the oscilloscope's main specification. It says how high a frequency it can measure. There is a "gotcha" here. For example, if a bandwidth is specified at 100 MHz, this means that the response at this frequency is down by 3dB or 30% (typically). So, if you are expecting to see a 1 volt signal at 100 MHz, you will see 0.7 volts. People tend to miss this point. Remember, higher frequency harmonics are present in any non-sine wave. These can be reduced or eliminated because of a limited bandwidth. For example, a 100 MHz square wave will look very much like a 100 MHz sine wave with a 100 MHz oscilloscope.

If all you ever wanted to do was

audio or TV servicing, you used to be able to use a 5 to 10 MHz 'scope. Well, that's yesterday. Today's TVs, stereos, CD players, and all the rest are using more and more digital circuits and higher frequency switching power supplies. And, don't forget remote controls, embedded microprocessors, digital signal processors, and so on.

You will need a bandwidth of at least 50 MHz for any digital work. This will show 20 nS glitches. For high-speed digital work, you should multiply your speed by four or five for your bandwidth. So, for a clock speed of 50 MHz, get a 200 to 250 MHz oscilloscope.

The usable "one-shot bandwidth" (for non-repetitive signals) of digital 'scope is about 20% to 25% of the sampling rate. This value is most compatible to the analog 'scope's bandwidth. However, digital 'scopes have the capability of constructing an image of the signal by taking multiple samples and adding them together. So the "repetitive signal bandwidth" may be much greater. Know the difference.

This brings us to an important point. You should always get better equipment than you currently need. This is because it's engineering's nature to evolve. Things always work faster or with more precision today than yesterday. Getting a piece of test equipment that just meets your needs today will be inadequate tomorrow. Then you either have to buy a new instrument or try to use something that cannot provide you with the precision necessary. It makes more sense to budget a little extra now instead of paying a lot more in the near future. Instrumentation is expensive. You want it to last a while.

With oscilloscopes, try to get a multi-trace unit with dual time base (not just delayed sweep). It's almost like getting two oscilloscopes in one. The extra time base can be set to trigger on an event some time after the first trigger. It makes seeing parts of complex waveforms easy. For example, suppose you want to look at the 10th scan line in a video signal. Just set up the main trigger on the retrace signal and adjust the delay for the second time base trigger — which is on the sync signal. The trace will step from line to line with the turn of a dial. (I know of a person who had to spend a day or so breadboarding a complicated counter to accomplish this.)

If you need a frequency counter, get one with a high stability time base option (one part-per-million/PPM or better). Also, look closely at "universal" counters. These allow you to take ratio measurements between two different frequencies. This saves time and errors. Long, digital counter chains are trivial to troubleshoot. It's certainly very easy to see that 32,767 is not 32,768. Compare that with measuring one signal's frequency, measuring another signal's period (to get the needed resolution), converting from period to frequency, and then calculating the ratio (which will rarely be a whole number because of counter-gate uncertainty and rounding errors). Time is money.

Get a tracking generator when you buy a spectrum analyzer. (This is a sweep-oscillator that follows the scan of the spectrum analyzer.) It allows you to create frequency response curves for amplifiers and filters in seconds. For RF work, it can provide some of the capabilities of a network analyzer. It allows simple one-port (antennas) and two-port (amplifiers/filters) analysis.

I only touched on some of the most important basic pieces for your test bench. Obviously, there are many other types of test equipment. (If you want more details on more types of instruments, let me know.) Your specific needs will tell you what you should buy. With the exception of the oscilloscope bandwidth, you should always buy at least 10 times the precision you want to measure. If you want to measure to ±0.1 volts, you need a meter that measures ±0.01 volts. Otherwise, you will not be able to trust your measurements. And, if you can't measure it, how do you know it works?

Limits, Calibration and Standards

Take a fresh nine volt battery and connect it to two 10 megohm resistors connected in series. What is the voltage from the resistor-resistor junction to the minus battery contact? Measure it. It should be 4.5 volts. Most likely, your meter will indicate something much less. Why?

Simply, your meter places a load on the circuit. That's another way of saying that the meter acts like a high-value resistor parallel with the 10 megohm resistor. Most basic DMMs have about 10 megohm input resistance. Oscilloscope "1X" probes have 1 megohm resistance and "10X" probes have 10 megohm resistance. Analog multimeters vary and are identified with an "ohms per volt" rating. The point I'm trying to make is that you should always be aware of the limitations of your equipment. Forgetting this important issue will lead to confusion and perhaps other bad things. Test instruments are not perfect.

Additionally, test instruments age and wear out. This means that they should be periodically checked for proper operation. This is called calibration. It's basic industry standard to calibrate instruments every year or after every repair. This takes time and can be expensive if the equipment is shipped to a calibration facility.

Is it really necessary? Well, it depends. An experienced engineer will often notice significant (and sometimes not-so-significant) variations in performance with a familiar piece of gear. Additionally, most variations are subtle and are not too likely to cause problems. It can be really serious if the instrument is used by production people for precision measurements. For example, suppose someone is aligning a TV tuner with a 250 MHz signal (measured with a frequency counter) that is off by 1 MHz. Clearly this will cause significant TV reception problems in the finished units.

A short-cut for calibration is called 'confidence testing.' This presents known signals to the instrument to verify it's operating properly. In the above case, the frequency counter could be tested each morning with a separate and precise 250 MHz signal. It would only take a minute.

There are many simple ways to perform confidence checks on equipment. (A precision resistor measured very accurately, a good crystal oscillator, etc.) These *are necessary*. And, they should be performed with regularity — at least every month. Any variation in performance should be noted *on* the instrument. (Use something reliable. Yellow sticky notes are not acceptable.) Any significant variation from what's expected should be a signal to repair or re-calibrate the device.

Basically, confidence testing is "standards testing." You test a frequency counter with a "standard" frequency. Of course, this leads to the question of how good the standard frequency is and how it was measured, and so forth, and so on. Eventually, all standards return to basic measurements that are internationally agreed upon. NIST (National Institute for Standards and Technology) is the group that represents the USA. This is what is meant by "NIST Traceability."

Of course, you can buy "Standard" items that are directly traceable to NIST, but they are expensive. On the other hand, they can be amazingly accurate. For example, I recently got a voltage standard (Standard Cell) from a local company that was going out of business. It was made by The Eppley Laboratory in Newport, RI. I called them to see when it was made. Mr. Richard Eggerman told me it was made in the 1960s or 1970s, and in 1996 (the final year they made them) they sold for about $425.00. The voltage marked on the standard is 1.01905 volts. I measured it to be 1.01857 volts. Only a change of 480 μV over 30 to 40 years!

Thinking is the Best Test Instrument

Good test equipment makes testing easier. Making testing better requires thought and understanding. You can improve the accuracy and resolution of many measurements with simple statistical proceedures.

It's tedious, awkward, and time consuming. But, 10-fold to 100-fold improvements in accuracy and resolution can be accomplished this way. This means that you have the potential to turn the fast 8-bit A/D in your microprocessor into a very slow 12-bit A/D. Under some circumstances, this may be a perfect answer to serious problems.

You need to understand both the instrument and the test to get the most out of your gear. Do you know how dual time-bases work? Or, how a universal frequency counter differs from a basic one? Or, that a tracking generator makes filter testing a snap?

These points are learned through experience and a willingness to learn. Read the instruction manual. I'll bet it will show you many ways to use that piece of gear that you didn't know about before. Watch and learn from others. Ask questions. Testing is fundamental to many aspects of engineering and to the business of engineering.

Here's a good example. A while back, an engineer friend's sports car wouldn't start after dinner at a restaurant. He had a basic tool kit with screwdrivers, pliers, and some insulated wire. It seemed clear to him that there was a problem in the battery cables. But, the car had two six volt batteries behind the seat and many connections. Which was the bad one? My friend made a simple test instrument.

He took a piece of insulated wire and electrically connected one end to ground. Then, starting at the starter, he briefly touched each connector until he found the one where the battery current caused big sparks and the wire got hot. That showed him the last good connection in the series. He was able deduce that the previous connector had to be the bad one. With his other simple tools, he was able to clean the connector and start the car. Elapsed time: less than 30 minutes.

Conclusion

The practical aspects of testing cover a large number of areas. Understanding how testing is accomplished, how test instruments work and the limits of test equipment will enable you to make the most out of your time and money. Whether you are a hobbyist, design engineer, or entrepreneur, learning about the techniques of testing will always be worthwhile. **NV**

Continued from Page 55

only require replacing the modem on your server with a ISDN terminal adapter.

There is also the new V.92 standard, unfortunately it won't help you since it is only an improvement in the upload speeds of V.90. For a more complete explanation, check out **www.v90.com**

Bill Curry
Baton Rouge, LA

[09034 - September 2003]

I need to buy a submersible water pump. The pump runs off 120 VAC and has a line cord attached. The idea of putting a line cord in water just makes me weak at the knees. Can I use two wall-warts (both 9 VAC), one plugged into the wall with the output connected to the output of the other wall-wart? This should give me back an isolated 120 VAC at low amperage, right? The pump is rated at 120 VAC 0.09 amps.

#1 Although your idea sounds novel, it's not the way to go. Your fears are well founded, 120 volts and water don't mix. However, we do live in the 21st century and cheap cures are available and safer.

Install a GFI into your wall socket where you get your power for the pump, and any possible short to ground or water will trip the circuit off like a fuse or circuit breaker, but much faster.

All modern devices that involve water and power are required to have these nowadays and that includes kitchen appliances and bathroom receptacles. They usually retail for less than $10.00 and they are the only way to go. (GFI stands for Ground Fault Interrupter.)

Chris Bieber
CA

#2 I share your concern about mixing 120 VAC and water but I've had *very* good luck with pumps of this type. One has been in continuous operation here for over 10 years with no difficulty. However, there are a couple of ways to improve the safety.

Your idea of two back-to-back wall warts is a good one with one exception — current! Although you didn't specify the wattage of the motor driving your pump, even if it is a small one, it most likely consumes 100 or more watts of power. This translates to approximately 1 amp at 120 VAC. There is no way your wall warts rated at .09 amp are going to be able to supply the needed current. Furthermore, one amp at 120 VAC translates into over 13 amps at VAC which the transformers must also carry!

There are a few ways to do what you want:

1 - Use much larger transformers rated for the neccessary current.

2 - Purchase a 120 VAC isolation tranformer rated for the current needed by the motor.

3 - Purchase a ground fault interrupter and plug the pump motor into it. This will remove power the instant there is any type of current leakage between the AC power mains and a path to ground and is a lot cheaper than a transformer with the needed current capacity.

K3PGP - John

[08037 - August 2003]

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

Depending on what your needs are, as far as precision, and repeatability, both short- and long-term, something as simple as the ubiquitous "555" chip would work. It's readily available, dirt cheap, and you can set oscillator frequency with a simple R/C circuit. By simply using several momentary-contact push-buttons to switch in different R/C resonances, you can make it tweet at different pitches.

That 'simplistic' 555-based circuit will suffer from 'drift' over time, and as temperatures change but it is not likely that each pitch will drift an 'equivalent' amount.

A high-precision, high-stability, version would use a temperature-compensated, crystal-controlled oscillator reference, a programmable divider circuit, and a voltage controlled oscillator in a PLL circuit to generate the pitches.

By using a single reference, you insure that, if any drift occurs, that all the generated pitches will shift in the same direction, and by proportionate amounts — i.e., relative pitch will still be perfect, even if absolute pitch is a little bit off. With typical crystal accuracies measured in parts per million, this kind of design will probably hold Concert A within ±0.01 Hz, without any special effort. With care in the design, one can easily add another one or possibly even two zeroes.

Robert Bonomi
Evanston, IL

[09035 - September 2003]

I am setting up a data acquisition system for use on a small boat and was contemplating using a mini PC like FIC's Ice Cube or Brick. I'm trying to keep the power consumption of the system down and have been looking for any "weak links in the chain." I hate the idea of using a voltage inverter to step up the 12-volt battery output to 110 VAC so I can plug my computer power supply in, which then converts back down to ±12, ±5 VDC, etc.

Does anybody make or have plans for a DC-to-DC power supply for computers that is a direct replacement ATX or mini ATX format? Are there people out there who only use computers from batteries? I will have this system on eight plus hours a day, so I can't use my laptop, as the battery only lasts two hours at best.

There has been a circuit described in *QST* July 1997. Sam Ulbing N4UAU designed this neat little booster for what Mr. Lenardi needs. It can be found at **http://user.gru.net/n4uau/kits/Booster%20QST.pdf**

I remembered this because I needed a circuit like this and it seems to be efficient, flexible, and easy to build. Hope I could help.

Christian Bock
Longview, WA

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