

Don Lancaster's

Hardware Hacker

Selected reprints — volume III

Radio-Electronics series (January 1990 - December 1991)

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Box 809, Thatcher, AZ 85552 (602) 428-4073*

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Introduction

Welcome to the third volume in our ongoing series of my *Hardware Hacker* reprints from *Radio Electronics* magazine. Who have recently renamed themselves *Electronics Now*. This volume includes the January 1990 through December 1991 columns.

As before, I do use the term "hacker" in its original context, namely anyone who is genuinely interested in pushing all the limits of software and hardware and is willing to do so in a fully cooperative, low cost and sharing network environment.

I've tried to expand the topics beyond the strict boundaries of traditional electronics. Going into the science and math subjects many of you have asked for over our voice helpline. And even looking at controversial pseudoscience and "free energy" topics.

My goal in flirting with the "not even wrong" pseudoscience and perpetual motion stuff is to pile it up on center stage and shine a bright light on it. To get you to conclude that "Yup, that sure is a big pile all right." Very little of this can withstand critical inquiry.

Some of the more popular subjects in this volume include fractals, chaos science, alternate energy, electronic levels, magnetic refrigeration, vortex coolers, video compression, wavelets, caller id, data curve fitting, and GPS navigation. Plus dozens more.

Preprints and reprints of most of my columns are also available electronically via *GENie* PSRT, presented in *Hacker Data Format*. For *GENie* access, have your modem dial (800) 638-8369. Just as soon as you verify your software connect, enter an HHH. After the prompt, enter JOINGENIE. When you are asked for your keycode, enter DMD524.

I continue to offer my no-charge voice helpline at (602) 428-4073, and offer free referrals from our *Synergetics Consultant's Network*. I've also got a free and newly expanded *Hardware Hacker Inside Secrets* and catalog waiting for you when you call or write. You can also grab this as SYNCAT1.PS off *GENie* PSRT, or else request one through my *Internet* address of SYNERGETICS@GENIE.GEIS.COM.

The *Electronics Now* subscription number is (516) 293-3000.

About the Author

As he said in his classic *Incredible Secret Money Machine II*, Don Lancaster writes books. And quests *tinajas*.

Microcomputer pioneer and guru Don Lancaster is the author of 28 books, 2 videos, and countless articles. These include his *TTL Cookbook* and *CMOS Cookbook* internationally published million seller classics. Don is considered by some to be the father of the personal computer, for his early ground-breaking work with hacker digital electronics and low cost video terminal displays. He is considered by others to be the patron saint of the Walter Mitties of the World. And by yet others as the... Uh, I guess we better skip that one.

Don is the *Hardware Hacker* in *Electronics Now* (516) 293-3000, runs his *Resource Bin* in *Nuts & Volts* (714) 371-8497, and is the *Blatant Opportunist* in *Midnight Engineering* (719) 254-4558. Don is also the sysop for *GENie* PSRT, a leading Hardware hacking, PostScript, laser publishing, and money machine on-line resource. His *Ask the Guru* columns continue to be published electronically on PSRT. For fast *GENie* modem access, dial (800) 638-8369. Then HHH followed by JOINGENIE and DMD524.

Don is also the head honcho of *Synergetics*, a new-age design and consulting firm that specializes in computer applications, laser printing, PostScript development work, electronic prototypes, Book-on-demand publishing, technical writing, and innovative software design. His avocations include firefighting, cave exploration, bicycling, and, of course, *tinaja questing*.

Don maintains a no-charge voice helpline at (602) 428-4073. He does welcome your calls and letters. The best calling times are 8-5 weekdays, *Mountain Standard Time*. Referrals to Don's *Synergetics Consultant's Network* are available through this same number. ♦

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Let us start off with some new update info for our previous columns. The 38.4 Kilohertz crystal needed for the stereo broadcaster is available for around \$3 from *Statek*, who stock quite a wide variety of small and cheap low frequency crystals.

Because 38.4 kHz is now a standard modem value, it might end up a better choice than the usual 38.0 kHz stereo multiplex frequency, and should work out just about as good. Probably your best way to assemble this project, though, is to go to one of the kits offered in the classified section.

UPDATE: Improved circuits can be found in *Hardware Hacker* #52.

One interesting use for this chip is to measure the torque on a rotating shaft. A \$1.50 part can easily replace a \$1100 telemetry system, at a lower power and smaller size.

Two additional sources for heavy water (deuterium) are that *Canadian Atomic Energy Commission* and their *Isotech* reps here in the US. Price is in the forty cents per gram range. But do note that heavy water weights twice as much as regular water, or roughly two grams per cubic centimeter.

A key cold fusion paper appears on pages 301-308 of Volume 261 of the *Journal of Electroanalytical Chemistry*. The *EPRI Journal* (the Electric Power Research Institute) for August 89 also has some interesting info.

A few of you callers on our hacker helpline have suggested faking those high priced linear actuators that we looked at two columns back. To do this, select an ordinary stepper and couple it to a piece of threaded rod by using shrink tubing. Then add two nuts and some sort of a platform to make up a traveling slider.

Various tricks could eliminate any backlash, and you should be able to replace a \$57 list price actuator with a surplus \$2 stepper this way.

As per usual, all of our names and numbers have been gathered together into the ending appendix.

We seem to have a mixed bag for this month...

Thermoelectric Coolers

There sure appears to be a lot of hacker interest in the thermoelectric cooling devices, so let us have at it. We'll start off with the bottom line – Besides their very high costs, these devices are pretty much useless, since they are so incredibly and horribly inefficient. They are only workable for very specialized and arcane applications where nothing else will do. Thermo coolers will work only when you go to ridiculous extremes on insulation and heatsink efficiency, and then only are capable of pumping tiny amounts of heat.

And, to further shatter some hacker dreams, no way will they make ice in the real world.

At any rate, a *thermoelectric module* is a solid state cooling device. All you do is input a dc current, and heat moves through the TE device, cooling one side and heating the other.

Figure one shows you a typical device. This one's the *Cambion* model 801-2007. A similar component is also now available through *Melcor*. This module measures about two inches square and can move up to 22 watts of heat when powered by a 12 volt car battery at 7 amps. Cost new is in the

\$20-30 range.

Solid state cooling modules use the *Peltier effect*. Figure two shows you details. What you do is start off with bismuth telluride or some other semiconductor. Then you cut it up into blocks while heavily *p* doping some of them and *n* doping others.

When a current is applied in the proper direction, the electron carriers in the *n* material and the hole carriers in the *p* material will "drag" thermal energy along with their motions. In both cases, the towed heat travels downward, creating a hot side and a cold side.

The amount of heat you can move depends highly upon the temperature differential you have to maintain. As figure three shows us, this particular device can provide a 60 degree C difference between the hot and cold side *provided you pump zero heat through it*. On the other hand, if you do keep both sides at the same temperature, you can pump up to 22 watts of heat through the device.

In most uses, of course, you will both want to cool something off and transfer heat, so you must use the middle of the curve. For instance, you could pump eight watts of heat with a 40 degree centigrade drop. To put this

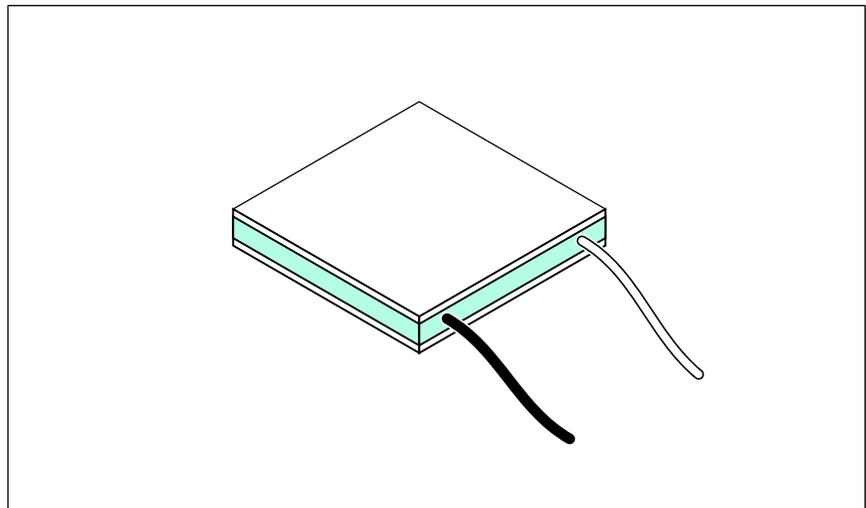


Fig. 1 – THERMOELECTRIC COOLING modules are fairly cheap and easy to apply, but they are so inefficient that they are pretty much useless for any higher-power heat pumping.

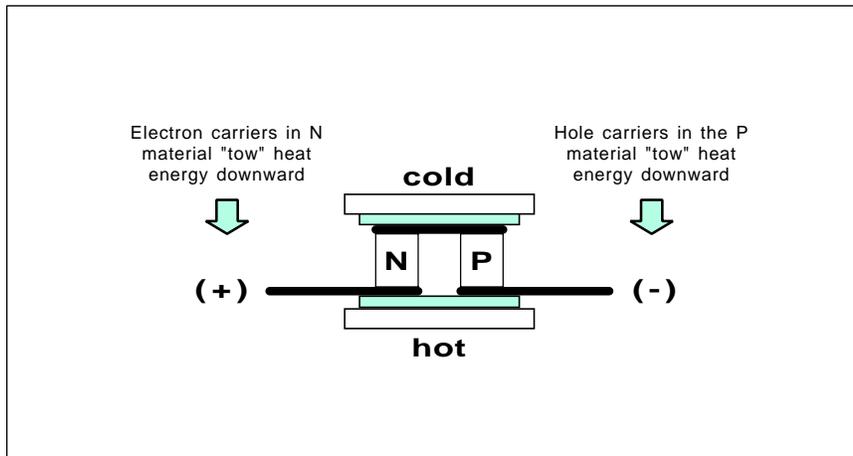


Fig. 2 – A THERMOELECTRIC MODULE consists of blocks of bismuth telluride that have been alternately n- and p-doped. The blocks are placed electrically in series and thermally in parallel. When a DC current is applied, electrons in the n material and holes in the p material will tow heat along with themselves. Heat is thus pumped from cold to hot.

in perspective, this module could, in theory, make a very small ice cube in around one hour. Assuming you've got ideal conditions.

The trouble is that conditions are *never* ideal for TE modules. There are a number of nasty gotchas which will gang up on you when you try to use them in the real world.

Thermoelectric modules are rather expensive, mostly because they have not been improved one iota in the last

two decades. Worse yet, all of these modules are horribly inefficient. In a typical use, you'd have to input five watts of input power to provide just one watt of cooling. Mechanical air conditioners are almost *fifty* times more efficient than this! Worse yet, you have to apply this extra heat to exactly where you do not want it.

The heatsink you connect the hot side of the module to must be absolutely flat, and be machined to within

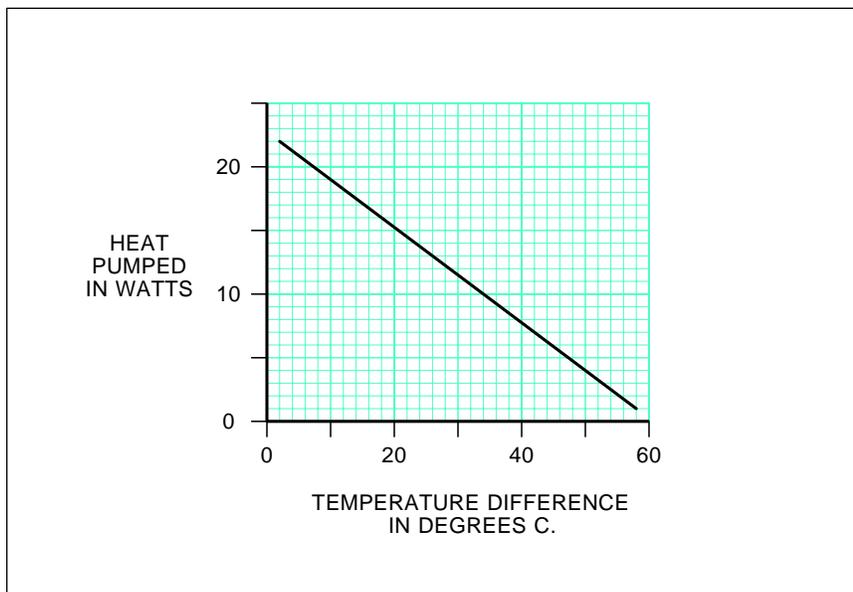


Fig. 3 – THE AMOUNT OF HEAT PUMPED by a thermoelectric module depends on the temperature drop you require. Note that the heat transferred at the maximum temperature differential is zero. Note also that the heat differential is with respect to the hot end of your heat sink, and not to ambient.

0.001 inch over its entire area. It must then get carefully covered with a thin layer of thermal grease. Obviously, those portions of a module not contacting the heatsink can not deliver any useful cooling.

The real killer to most TM module applications lies in the thermal drop between the heatsink and the ambient temperature. For higher power uses, a fan or water cooling is essential.

For instance, a very large plain old heatsink will have at best a 1 degree C per watt temperature rise above the ambient. Say you want to pump the 8 watts at a 40 degree centigrade drop. The heatsink will have to sink these 8 watts, plus an additional 32 watts or so of the input power for a total of 40 watts. At 1 degree C per watt heatsink rise, the heatsink will warm up to 40 degrees C *above* your ambient room temperature.

And you've done nothing but break even! The cooling module has a 40 degree *drop* across it. Your heatsink has a 40 degree *rise* across it. And the net cooling is *zero*. You have nothing at all to show for all your effort.

One more time. In this previous example, your final cooling is zero, because the hot side of the heatsink rises just as much *above* ambient as the amount of temperature drop you are trying to achieve! And a one degree per watt heatsink is a darn good one. And large, too.

So, an extremely low thermal drop from heatsink to a room ambient is absolutely essential. Also essential is an incredible quantity of insulation around whatever you are cooling, for any net heat flux into your area being cooled will only make matters much worse than they already are.

The modules can get reversed by reversing the current. Because of the inefficiency, the heating mode is five times more effective than the cooling mode. Watch this detail.

One side effect of this inefficiency is that you must run the modules off of a nearly pure direct current. The least amount of power supply ripple will dramatically chop your cooling ability, since the ripple troughs will heat five times better than the ripple peaks will cool your load.

A car battery is often your best choice to power your TE modules. You might temporarily demonstrate a

module simply by holding a module between your thumb and finger and then connecting up the module to a single alkaline "D" cell. Do not use the "D" cell for more than a very few seconds at a time.

What good are TE modules? You definitely can't buy a 4 x 8 foot panel of these and use them to air condition your house. But they are lots of fun to play with. These are a sure-fire topic for a winning science fair project or student paper. Besides that, though, thermoelectrics are limited to those specialized and low load uses where nothing else can do the job. Important uses include coolers for infrared detectors, dew point humidity sensors, chillers for microscope stages, and for thermal management control in satellites.

I have often wondered why these do not get used in satellite receiver front ends. I guess the answer is that the gain of the input amplifier drops faster with temperature than the noise figure improves.

Both *Cambion* and *Melcor* do have lots of interesting tech literature on thermoelectrics, so you might want to contact them both for more info.

Other Coolers

There's three other approaches to unusual cooling techniques that are hacker hackable. You just might want to pick up on these instead.

First, Japanese air conditioners are ridiculously better than the American ones, and have been for the past few years. It seems that all the American manufacturers refuse to pick up on this new technology, blaming the building codes, and claiming that a customer demand does not exist.

These new air conditioners have EER efficiency ratings approaching a value of 15, meaning that they use 33 percent less electrical energy than ours do. That's \$60 per month or so. They are also much quieter and far more comfortable. Four of the secrets include a new beastie called a *scroll compressor*, a motor that provides a near infinitely variable speed on the compressor, a similar variable speed blower on the air handler, and a total programmed controller.

I guess you would call this second device a solid state cooler, although you will need a large air compressor

across the room for a power source. At least the extra heat isn't generated at precisely the wrong place, as is the case with TE modules.

It turns out that rapidly moving air accepts heat from slowly moving air. Thermodynamics and all. So, if you build a suitable *vortex nozzle device* having one inlet for shop air and two outlets, you can arrange things so that cold air comes out one end and hot air out the other. With zero moving parts. Believe it or not, you can get as cold as the -40 degrees Fahrenheit dry ice temperatures, or else you can trade off flow rates to get maximum heat pumping at lower differentials.

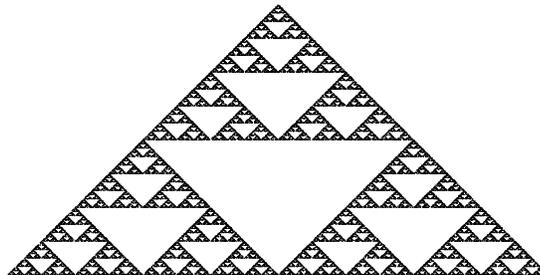
One obvious use for these is as needle coolers for industrial sewing machines. Any heat-caused needle breakage can be almost completely eliminated by using a vortex nozzle.

The leading manufacturer of vortex cooling nozzles seems to be *Vortec*. Besides offering bunches of free data and free cassette tapes on vortex cooling, they also have a number of other unusual nozzles that can do such things as air amplification.

Another source is *Exair*.

As a third approach to effective cooling, dry ice machines are amazingly low cost and simple. *Edmund Scientific* is one source. All you do is connect the machine to an also cheap carbon dioxide tank from your local gas supplier and turn it on. Slightly over half the gas expands and boils off, while the rest of it will cool and solidify into one solid block. Presto. Instant cold.

Naturally, you do this only in a highly vented area while you are wearing safety glasses. You also will



```

/problistcreate {mark /counter 0 def probabilities {128 mul round cvi {transforms
counter get} repeat /counter counter 1 add def} forall counttomark 128 sub neg
dup 0 gt { [1 0 0 1 0 0] repeat} {pop} ifelse] /problist exch def} bind def

/doi {problistcreate 1 1 20 {problist rand -24 bitshift get transform 2 copy moveto
0.001 10 rlineto} repeat newpath numdots {problist rand -24 bitshift get transform
2 copy moveto 0.001 0 rlineto stroke} repeat} bind def

% /// demo - remove before use. ///

/numdots 6000 def % increase for denser image; decrease to print faster

/transforms [
[0.5 0 0 0.5 0 0]
[0.5 0 0 0.5 1 0]
[0.5 0 0 0.5 0.5 0.5]
] def

/probabilities [ .33 .33 .34 ] def

1 setlinecap 0 setlinewidth 200 300 translate 100 dup scale doi
showpage %quit

```

Fig. 4 – A SERPENSKI TRIANGLE STRANGE ATTRACTOR done by using PostScript. While you can enter this into most any word processor on any computer, a printer that accepts PostScript is needed for your final output.

want to prevent the instant frostbite caused by carelessly handling the finished product, or otherwise letting it come into skin or eye contact.

Another Contest

In case you have not noticed, the bottom has once again fallen out of the memory chip market, eliminating that insane two-year pricing blip that was a direct result of some incredibly stupid and monumentally misdirected government meddling in free trade. Your jellybean 1 Megabyte dynamic RAM chips can now be gotten in quantity for as little as \$8 each. That translates to around 800 *microcents* per bit. And hackers can once again rejoice. Yea team.

Now, depending on who is doing the counting, the human brain will contain the equivalent of four billion

memory bits or so. That's equal to a dozen CD ROM platters or a small shoebox full of the 1 Meg x 8 SIMM strips. It's also equal to a mere *eight* of the new 64 Meg x 8 SIMM's just beginning to emerge from their preliminary lab research stage.

Projecting these ongoing memory trends, in around ten years or so, *machines will definitely be smarter than people*. So, for this month's contest, just write me a short essay on exactly what happens when machines will inevitably become the most intelligent life form on earth.

We'll have all the usual *Incredible Secret Money Machine* book prizes for the dozen or so best entries, with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the top entry of all. As usual, all entries have to be on paper, and should get

sent to me here at *Synergetics*, rather than to **Radio-Electronics**.

Now, there's a memory effect that nobody talks about very much, and its implications for machine intelligence are genuinely scary. I like to call this the *threshold effect*. Your threshold effect goes like this: *If you double the size of any memory, the performance capabilities of that memory usually will increase by much more than a factor of two*. This happens because the arrangement and the use of your memory can now be better organized and can more effectively perform new higher level functions.

For instance, some of your smallest microcontrollers only have room for a single hand-coded program. Add a little memory, and you can step up to a *system monitor* that gives you more power and control. More memory and you step up to some *interpreted language*. More still, and you pick up a sophisticated *operating system*. The next level gives you fancy *toolboxes*, and *integrated programs*.

The level beyond that can give you powerful new levels of organizing the programs themselves. *HyperCard* and its mutants are an obvious example here. Beyond that lies all the *expert systems*, *massively parallel architectures*, and *artificial intelligence*.

Because of these threshold effects, going from a 4 Megabit memory to a 4 gigabit one will gain you far more than a paltry 1000:1 in performance abilities. I feel that something like a million to one is more like it.

It would seem to me that there are probably three or four brand new and previously unthunk of thresholds that lie between where we are today and where we will be when we get up to routinely being human brain sized a decade from now.

What are these thresholds and when will they get crossed? Knowing the correct answers to this one could make you filthy rich in a hurry.

Chaos and Fractal Resources

There is a new endeavor known as *Chaos Science*. Actually, it's really a loosely knit collection of all sorts of unusual old and new stuff, much of it only weakly related, if at all. As a general rule, if it keeps a math freak off the street at night and if it looks pretty in an alien sort of way, then it



```
/problastcreate {mark /counter 0 def probabilities {128 mul round cvi {transforms
counter get} repeat /counter counter 1 add def} forall countmark 128 sub neg
dup 0 gt { [1 0 0 1 0 0] repeat} {pop} ifelse} /problast exch def} bind def

/doing {problastcreate 1 1 20 {problast rand -24 bitshift get transform 2 copy moveto
0.001 10 rlineto} repeat newpath numdots {problast rand -24 bitshift get transform
2 copy moveto 0.001 0 rlineto stroke} repeat} bind def

% /// demo - remove before use. ///

/numdots 6000 def % increase for denser image; decrease to print faster

/transforms [
[0 0 0 .16 0 0]
[.2 .23 -.26 .22 0 1.6]
[-.15 .26 .28 .24 0 .44]
[.85 -.04 .04 .85 0 1.6]
] def

/probabilities [.01 .07 .07 .85 ] def

1 setlinecap 0 setlinewidth 200 300 translate 30 dup scale doing
showpage %quit
```

Fig. 5 – A FRACTAL FERN DONE IN POSTSCRIPT. Note that only 28 data values are needed to define this image. But what's really astounding is that you don't really "draw" this fern – instead, you simply let it out!

probably can be called chaos science.

Since chaos science is futuristic, utterly and totally bizarre, and more than eminently hackable, it should be of foremost interest to most of you **Radio-Electronics** hackers.

Our *Chaos Science Resources* sidebar will give you a quick summary of several of the main places to go for further info on this exciting new field. You'll probably want to start off with James Gleick's book *Chaos – Making a New Science*. This one is a thorough and easy-to-read but often shallow introduction.

The horse's whatever document, of course, is Mandelbrot's *Fractal Geometry of Nature*. While more than pretty to look at, this text is pretty nigh unreadable and is laughingly and pompously egocentric.

The book I am currently the most impressed with is the new *Science of Fractal Images*, especially in chapter five. A good summary did appear in the January 1988 *Byte* under the title *A Better Way to Compress Images*.

One of the things that struck me about this great book and the *Byte* summary article was that the sample BASIC and C programs were forever making those complicated translate-rotate-scale transformations. All the kind of stuff that *PostScript* does free, invisibly, and automatically all of the time. Contrary to all the dire negative comments found early in the red book, *PostScript* should end as up *nearly ideal* for any fractal geometry uses, along with nearly anything else involving chaos science.

An Unusual Fractal Fern

To test out this theory, I translated and then upgraded the original code into the *PostScript* routines found in figures four and five. These will give you a typical chaotic beastie known as a *Serpenski* triangle, plus *the fern*, the second most popular fractal image of all time. Of course, the *Mandelbrot Set* is numero uno, and I am saving it for sometime later.

Although you can run this code through any old word processor, you do need a *PostScript* speaking laser printer or a *PostScript* emulator to get your final copies. You could reverse engineer these back into BASIC, or else use the original listings as they appeared in the *Byte* article.

FRactal AND CHAOS SCIENCE RESOURCES

Beauty of Fractals, by Peitgen and Richter

Earlier text that is both a coffee table book and a source of useful algorithms. From the same publisher that did the *Science of Fractal Images*. (Springer-Verlag, 1986)

Springer-Verlag, 175 Fifth Avenue, New York, NY 10010 (212) 460-1500

BYTE Magazine

Occasional fractal articles and reviews. See *A Better Way to Compress Images*, January 1988, pp. 215-223 in particular.

Byte Magazine, One Phoenix Mill Lane, Peterborough, NH 03458 (603) 924-9281

Chaos – Making of a new Science, by James Gleick

Interesting and easily read survey of the entire field of fractals and chaos science. Frustratingly shallow at times. (Viking, 1987)

Viking Penguin, 40 West 23rd Street, New York, NY 10010 (212) 337-5200

Fractal Geometry of Nature, by B.B. Mandelbrot

The original "horse's whatever" book that started it all. Mind blowing artwork in an otherwise unreadable and excessively egocentric text. (W.H. Freeman Press, 1982)

W.H Freeman, 4419 West 1980 South, Salt Lake City, UT 84104 (801) 973-4660

Science of Fractal Images, by M.F. Barnsley et. al.

Outstanding collection of useful hands-on fractal information. A good starting place to extend your own research. Includes algorithms and a good bibliography (Springer-Verlag, 1988)

Springer-Verlag, 175 Fifth Avenue, New York, NY 10010 (212) 460-1500

SCIENCE Magazine

Occasional fractal and chaos science articles and reviews.

Science/AAAS, 1333 H Street NW, Washington, DC 20005 (202) 326-6400

SCIENTIFIC AMERICAN magazine

Occasional fractal articles and reviews. See their *Computer Recreations* column for ongoing info and comments.

Scientific American, 415 Madison Avenue, New York, NY 10017 (212) 754-0550

SIGGRAPH Proceedings

Far and away the best annual computer graphics show. Includes the latest and best of fractal and chaos science developments, on all three levels – theoretical, tutorial, and artsy-craftsy. (Siggraph-ACM Press, annually)

Siggraph/ACM Press, 11 West 42nd Street, New York, NY 10036 (212) 869-7440

Even though there still is an awful lot of slop left in this code, I was quite pleased with the final results and their speed under PostScript. I did elect to create a single custom probability table once ahead of time, rather than making slower individual probability selections on the fly. By providing for 128 entries in this table, rather than the expected 100, does give us some further speedup and simplification. But a lot more cries to be done.

When you are experimenting with these on your own, be sure to change the **numdots** variable to something in the high thousands for your original fast printing samples that will image in a few seconds to a minute or two. Later on, you could increase **numdots** as high as you need to for top quality final images that might take hours to print in their larger sizes.

Ultimately, you can convert the fern into a super fast printing image. Full details in #336 FASTFERN.PS on my *GENie* PSRT.

One other gotcha: The six element matrices used by the original fractal people and PostScript differ slightly. To get from one to the other, simply *interchange your second and third numbers in the array*.

Never mind why.

There are some amazingly bizarre things about the fern image of figure three. First and foremost, larger sizes of this fern original are hauntingly beautiful. In fact, I've never seen *any* PostScript code image *anywhere* that comes even remotely close. I do hope our **Radio-Electronics** printing process left at least a hint of this for you.

Second, the smaller pieces of the fern are definitely *not* a smaller, or *selfsimilar* copy of your whole picture. Unlike ordinary pictures, as you magnify, additional and uniquely different detail appears. But that is what fractal stuff is all about.

Third, although an apparently random process is used that picks four tasks by using random probabilities in random orders, you always end up with the *same* final image! This will happen regardless of which random numbers get used in which order.

This is a stunning example of a *strange attractor*, otherwise known as the holy grail of fractal-dom. As you might expect, others are seeking

out those possible strange attractors thought to underly the stock market prices and weather patterns.

Despite this, a sick random number generator will definitely not perform. You do have to use a good one. Short repetition sequences appear to be a no-no. Many more details on this in my *Apple Assembly Cookbook*.

Fourth, believe it or not, the *entire* fern is coded as only 28 numbers in a tiny data array! There's no difference whatsoever between your Serpenski triangle and the fern, except for these 28 numbers.

Nor is there any other difference between these and untold billions of other wildly differing images. So, we seem to have an absolutely incredible picture compaction scheme going on here. For a full page PostScript fern, your data compaction could approach 300,000:1! Unfortunately, though, your image regeneration times do get out of hand with compaction levels that are this high. You can forget about real time. In theory, by going to just a few more numbers, we can create *any* image at all. Which gets heavy fast.

Fifth, and finally, this image really does look just like an authentic Black Spleenwort Fern. Now, Black Speenwort Ferns have been around for a rather long time, and they sure are pretty, but nobody ever accused them of being very bright. Could the exact same process be used by the real fern to teach itself how to grow?

To me, the odds are overwhelming that this does seem to be the case. We thus appear to be tampering with some heavy duty stuff here.

What really astounds me over this fern, though, is that you do *not* really draw it. All you do is *let it out*, and it leaps out of its cage with a vengeance. I guess that is where the "strange" in *strange attractors* comes from in the first place.

Oh yes. If you do find the strange attractor that underlies stock market prices and send it to me, I'll be most happy to send you *five* of my money machine books. I might even consider a free *tinaja quest* as well.

Help Wanted

How about you helping me for a change? I'm having trouble finding some sources of cheap stock plastic

metric gears, especially the *Module 1.0* size. Any suggestions? Yes, *Stock Drive Products* does carry them, but at five times what I want to pay for them. A free book for your trouble.

New Tech Literature

Several manufacturers are newly turning to videotape product introductions. *Tektronix* has bunches of scope and spectrum analyzer tapes available for you. And *Sprague* has a free new "videotech paper" on a full bridge motor driver.

Speaking of *Sprague*, they also do have a unique new UGN3055U Hall effect device. These \$1.60 parts are *addressable*, which means that up to thirty of them can share the same two wire series query line.

From the *Phillips* branch of good old *Signetics*, a fat data handbook on *RF Power Transistors* and a rather detailed ap note on all those popular 74HC4046 phase locked loops.

The *SGS* people have a free soap-box full of EPROM samples for you, while *Texas Instruments* has a new free evaluation printed circuit board for their TL7770-5 supply voltage supervisor chip.

Here we go again. Bright blue light emitting diodes have been newly announced by *Sanyo*. Is this yet another false alarm? Time will tell.

Lightwave is a new and free fiber optics trade journal. And the *Quick Shooter* is a low cost plastic injection molding machine from *Haygean Machine*. This one uses a drill press for an injection ram.

Turning to my own products, I've recently upgraded and improved my book-on-demand printed *Hardware Hacker II* reprints, covering all of my hacking columns that have appeared in **Radio Electronics**. I've also just released a *LaserWriter Secrets* text covering my *LaserWriter Corner* columns over in *Computer Shopper*.

These new products are done using a fascinating new technique known as *Book-on-demand* publishing. Write or call me for more info on this unique new hacker opportunity.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8-5 in *Mountain Standard Time*. Let's hear from you. ♦

Don Lancaster's Hardware Hacker

February, 1990

Dew sensing circuits
Direct toner pc update
Midnight Engineering
Hacker cold fusion kits
Alarm & security resources

There's lots of exciting news this month, including cold fusion kits, an update on the direct toner printed circuit process, a major new hacker magazine, and some details on unusual dew sensor parts. So, let's just jump right on in...

Cold Fusion Kits

There seems to be lots of good news on the cold fusion front these days. At a recent conference, several more independent researchers now confirmed those excess heat production effects, verified expected nuclear byproducts, and offered lots of similar supporting observations.

See the October 27th, 1989 *Science* on page 449 for a good summary. The key sentence: "The experimental evidence for a cold fusion, or at least some unknown nuclear phenomenon, is too great to ignore."

At the same time, many of those earlier measurements and experiments have been made far more precise, and many possible error sources seem to have gotten eliminated. In particular, tighter control experiments involving non-deuterium and non-reacting cells have been carried out to the satisfaction of several prominent skeptics.

The general feeling seems to be that something really is happening here. And the most reasonable explanation for that something is that cold fusion is actually taking place, or else some previously unknown nuclear reaction seems to be occurring.

On the other hand, that excessive energy production is still very erratic, rather low, and highly unpredictable. Tremendous quantities of time and effort are usually required under extremely careful conditions to get any observable results at all.

There's been two major cold fusion developments this month that should be of major hardware hacking interest. The first is that all of the key fusion papers are now readily obtainable. And the second is that you can now get your own low cost (\$27) experimental cold fusion demonstration kit.

By the time you read this, over a

hundred key cold fusion papers should now be available by way of the *Dialog Information Service* that you will find through your local library. Figure one should get you started. I've listed two

dozen earlier papers, gotten through the *INSPEC* service within *Dialog*.

The costs of generating your own complete and up-to-date cold fusion abstract listing should be around \$35,

Cold fusion in metals

J. Kondo, *Journal of the Physical Society of Japan*, June 89, Vol 58 #56, pp 1869-1870.

Deuterium nuclear fusion in metals at room temperature

P. Tomas, *Fizika* (Yugoslavia), vol 21 #2, 1989, pp 209-214.

Exact upper bound on barrier penetration probabilities for cold fusion

A. Lettitt, *Physics Review Letters*, (USA), Vol 63 #2, 10 July 89, pp 191-194.

Cold fusion: how close can deuterium atoms come inside palladium?

Z. Sun, *Physics Review Letters* (USA), Vol 63 #1, 3 July 89, pp 59-61

Search for fusion reactions between deuterium atoms implanted into titanium

R. Behrisch, *Nuclear Fusion* (Australia), Vol 29 #7, July 89, pp 1187-1190.

Can solid-state effects enhance the cold-fusion rate?

A. Leggett, *Nature*, (UK), Vol 340 #6228, 6 July 89, pp 45-46.

Upper limits on neutron and gamma ray emission from cold fusion

M Gai, *Nature* (UK), Vol 340 #6228 6 July 89, pp 29-34.

Calculated fusion rates in isotopic hydrogen molecules

S. Koonin, *Nature* (UK), Vol 339 #6227, 29 June 89, pp 690-691.

Search for neutrons during heavy water electrolysis on palladium electrodes

S. Blagus, *Physics of the atomic nuclei* (Germany), Vol 333 #3, 1989, pp 321-322.

Screening corrections in cold deuterium fusion rates

K. Langanke, *Physics of the atomic nuclei* (Germany), Vol 333 #3, 1989, pp 317-318.

Cold fusion in the solid state?

J. Goedkoop, *Energiespectrum* (Netherlands), Vol 13 #6, June 89, pp 156-162.

Nuclear fusion

P. Bullo, *Elettrificazione* (Italy), #5, May 89, pp 57-61.

Theoretical considerations on the cold nuclear fusion in condensed matter

F. Parmigiani, *Nuovo Cimento D* (Italy), Vol 11D ser. 1 #6, June 89, pp 913-919.

Chemical forces associated with deuterium confinement in palladium

J. Mintmire, *Physics Letters A* (Netherlands), Vol 138 #1-2, 12 June 89, pp 51-54.

Cold fusion in condensed matter: is a theoretical description possible?

W. Schommers, *Modern Physics Letters B* (Singapore), Vol 3 #8, 20 May 89, pp 597-604.

Doubts grow as many attempts at cold fusion fail

B. Levi, *Physics Today* (USA), Vol 42 #6, June 89, pp 17-19.

Muon catalyzed fusion

C. Petitjean, *Fusion Engineering Design* (Netherlands), Vol 11 #1-2, June 89, pp 255-264.

Computation of the cold fusion rate

P. Dong, *New Physics* (South Korea), Vol 29 #2, April 89, pp 233-234.

The observation of 2.2 MeV gamma-ray in electrochemical cell

Y. Park, *New Physics* (South Korea), Vol 29 #2, April 89, pp 231-232.

First steps toward an understanding of "cold" nuclear fusion

T. Bressani, *Nuovo Cimento A* (Italy), Vol 101A ser. 2 #5, May 89, pp 845-849.

Emission of neutrons as a consequence of titanium-deuterium interaction

A. De Ninno, *Nuovo Cimento A* (Italy), Vol 101A ser. 2 #5, May 89, pp 841-844.

Fermi gas like hypothesis for Fleischmann-Pons experiment

O. Rossler, *Z. Nat. Phys. Chem. Kosmophys* (W Germany), Vol 44A #4, April 89, pp 329.

Observation of cold nuclear fusion in condensed matter

S. Jones, *Nature* (UK), Vol 338 #6218, 27 April 89, pp 737-740.

Electrochemically induced nuclear fusion of deuterium

M. Fleischmann, *Jour. Electroan. Chem.* (Switzerland), Vol 261 #2A, 10 April 89, pp 301.

Cold nuclear fusion

A. Rusu, *Energetica* (Romania), Vol 3 #6, June 88, pp 258-261.

On the practical use of the cold fusion (problems and prospects)

Y. Petrov, *Muon Catalyzed Fusion* (Switzerland), Vol 3 #1-4, 1988, pp 525-535.

Fig. 1 – SOME KEY COLD FUSION PAPERS. For a complete and up to date list, use the Dialog Information Service at your local library. Start with their INSPEC resource data base. Fleischmann's paper started it all.

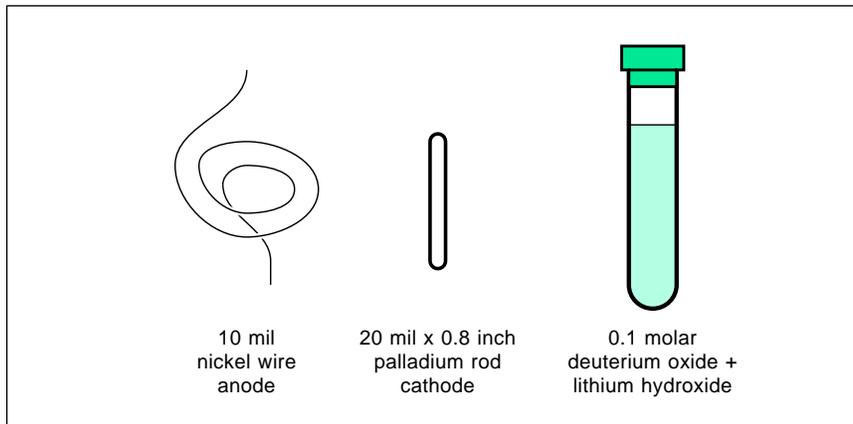


Fig. 2 – LOW COST HACKER FUSION KITS consist of a small test tube filled with heavy water, a short palladium rod cathode, and a nickel wire cathode. While the odds of positive results are rather low, this is a great show-and-tell item.

and should take twenty minutes.

As a reminder, the best sources for current info on cold fusion are in the *News and Comments* section found in *Science* magazine, and the *Technology* section that is usually found on page B-4 of your *Wall Street Journal*.

On to those kits. Guy Wicker is a name-brand hardware hacker and a well-known energy researcher. By a special arrangement, Guy has offered to put together a few new cold fusion mini-kits for all you **Radio-Electronics** hackers. The kits cost only \$25, plus \$2 shipping and handling.

As figure two shows you, this kit consists of a small test tube full of a 0.1 molar deuterium and lithium hydroxide solution, a short piece of 50 mil palladium rod, and a small loop of

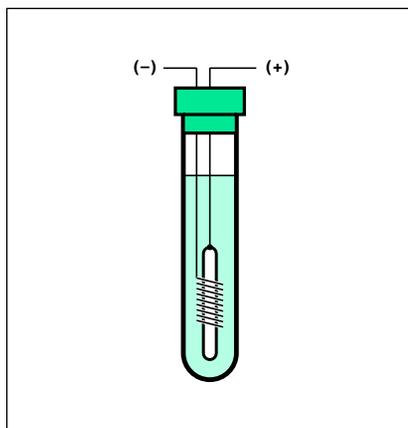


Fig. 3 – A TYPICAL COLD FUSION test setup. Apply a dc current around 10 mils. The anode and cathode should not contact. You measure for excess temperature, neutrons, and tritium.

nickel wire. Nickel is used instead of platinum for the anode.

A classic cold fusion cell is built up something like figure three. Use a coiled nickel wire anode, and a nickel suspended palladium rod cathode. You apply a test DC current in the 4 to 20 milliamperere range, with positive to the nickel anode and negative to your palladium cathode.

Be sure to carefully monitor your temperatures at several locations. If possible, also monitor for radiation. A "charging" time of several hours or a few days seems normal for this size palladium rod. Look for both a very low level and a separate "burst mode" excessive heat production effects.

Some sort of a continuous temperature recorder, possibly based on a personal computer, is probably a very good idea. You'll want to work inside of a styrofoam block which sits inside a picnic cooler or other insulated box.

Guy reports that very small cells like this one are far more likely to produce a low level tritium radiation than excess heat production. Getting both to happen at once when someone is watching is usually frustratingly difficult. It is also the Holy Grail of cold fusion.

Some warnings here. Your cell is extremely small and the excess heat production, if any, is likely to end up correspondingly tiny. Opportunities of cell contamination are very great. Your odds of your cold fusion cell working at all are only something like one in ten, and those odds of your being able to observe that operation when and as it occurs is also estimated as around one in

ten or so. Thus, your estimated odds are only one in one hundred that you will be able to prove your cell actually works.

So, what we have here appears to be a crap shoot.

On the other hand, here you do have a sure fire winner for a science fair entry, show-and-tell, or school report. And the "touchy-feely" and "See what I've got!" aspects of all these kits are completely off scale.

Golly gee, Mr. Science.

Guy also offers fancier cold fusion kits and similar products for serious researchers. Contact him directly for more information.

Needless to say, be sure and let us know the outcome of all ongoing test experiments. This is a wide open field with mind-boggling hacker potential.

UPDATE: As of fall 1992, cold fusion has largely failed to prove itself. No solid atomic evidence has ever been demonstrated, and the phenonomen has pretty much been downgraded to a lab curiosity. But dedicated researchers do continue their work.

Midnight Engineering

There's a brand new magazine out known as *Midnight Engineering*. It is specifically aimed at you hardware hackers and software developers who are trying to market their high tech products on a small-scale or startup basis. Its shoot-from-the-hip style is very much cast in the same mold as my *Incredible Secret Money Machine*. Emphasis is on real-world solutions and new hacker opportunities.

Free sample copies are available to you. This one is a "must have."

Printed Circuit Update

There sure were a lot of helpline calls and letters over our PostScript direct toner printed circuit lab prototype breakthrough in the December issue. I thought I would summarize some of your hacker suggestions to date. These appear in figure four.

Many of you totally and completely underestimated just how crucially important the PostScript language is to this breakthrough process. Among its many other advantages, PostScript lets you exactly trim your final image size to precisely 1:1. PostScript is output independent, meaning you could use either a desktop laser printer or a more precise phototypesetter; easily lets you

work at 1X, 2X, 4X, frontwards or backwards, normal or reversed, to as many as eight layers at once; has no upper size or any complexity limit. It is also totally host independent, which allows you to use any old word processor on any old personal computer; simply lets you pass layouts over any BBS system in the world as a plain old textfile; and is compatible with virtually all of the existing CAD/CAM programs, either through a direct PostScript driver or by a PostScript HPGL emulator.

Similarly, using the heated roller method works far better than an iron. The obvious reasons for this are the far more uniform pressure and temperature. You also can gain bunches in dimensional stability, since the mylar transfer sheet does not get any chance to distort all at once. As we've seen I do recommend a fake *Kroy Kolor* machine to do the transfer. We'll look at some cheaper alternatives for this in a future issue.

Several readers have now suggested substituting *Kapton* film instead of the polyester overhead sheets since it has better high temp stability. Two of the sources for *Kapton* include *DuPont* and *Rogers Corp.*

It also seems a very good idea to do your final cleaning wash of your bare copper board with distilled water. A brief pre-etch before transferring your toner image does appear to be quite important as well. The etch will both guarantee an extra clean board and gives you just the right "tooth" for the toner to grab onto.

Some other suggestions: preheat the copper board as much as you can before doing the transfer. The idea is to keep the copper from acting as a giant heat sink. Something around 150 degrees Fahrenheit should work. Note that gloves are an absolute must.

And rub an ice cube on the back of the transfer sheet before separating it from the pc board. This seems to improve the transfer process bunches.

Be sure and send in your own tips and techniques for getting perfect 1:1 toner transfers. When all of the dust settles, we'll try to separate the black magic from the reality and standardize on a useful direct toner process.

UPDATE: Vastly improved direct toner products appeared in fall of 1992. Especially from *DynaArt Designs* and *Technics Inc.*

Alarm and Security Resources

To continue our ongoing series of resource sidebars, this month we'll look at what you'll need to know to pick up insider information on burglar alarms and security systems. The magic names and numbers appear in that *Alarm and Security Resources* color sidebar.

As with any field at all, your best bet is to start with the trade journals. A complete listing of all trade journals is available as the *Uhlrichs Periodicals Dictionary* on the reference shelf at your neighborhood library. A second source that appears almost as good is that *International Standard Periodicals Dictionary* on the same shelf.

Typical trade journals for this field include *Security Dealer*, the *Security Distributing and Marketing*, and the *Alarm Installer and Dealer*.

Trade shows play an important part in the alarm industry. A pair of the largest are the *International Security Conference & Exposition*, and *The Security Show*. These do move around from town to town. Check any of the trade journals for show dates.

There are a number of specialty wholesale distributors that cater to the alarm trade. You'll find lots of ads for these in all the trade journals and their directories. Three larger examples are *King Alarm*, *Arius*, and *Ademco*.

Two sources of general installation tools and test instruments do include

Jensen Tools and *TechniTool*. Sadly, both of these yuppieized outfits are rather pricey. But all of their products are both first rate and top quality.

There are now hundreds of security consultants that will be glad to help you for a sane and reasonable fee. Two examples here are Wyatt Palmer (no relation) of *Valley Security*, and Jeff Lancaster (my widdle brudder) of his *Cain Security Systems*.

Please let me know if you know of any other resources you think should be added to this list.

Dew Sensors

We've looked at humidity sensors in several earlier columns. One unique and low cost humidity detector is called a *dew sensor*. These cost only a dollar each and are intended to protect moisture-sensitive VCR drums.

Three typical part numbers would be the *Murata* HOS 101-100, the *Taiyo Yuden* TD-P-100, or that *Panasonic* EYH-S0210.

Unlike hygrometer sensors, these devices should have a fairly low and uniform dc resistance whenever no moisture condensation takes place. A typical dry resistance value is 10K.

At a 100 percent humidity, the air retains all of the moisture it possibly can. Beyond this, the moisture in the air will condense out, forming rain or a dew coating.

A special moisture sensing paint

1. The PostScript language is essential to the direct toner process. Its totally overwhelming advantages include precise scaling to 1:1, total format flexibility, host and printer independence, easy BBS downloads, and the ability to use nothing but a word processor.
2. Heated roller transfer methods work much better than an iron. Use a fake *Kroy Kolor* machine or its equivalent. The reasons include better stability and tighter temperature control.
3. Use a "dry" (silicon oil free) fuser wiper pad for several copies before your transfer sheet is run.
4. For extreme dimensional stability, try using a *Kapton* film, rather than polyester or mylar.
5. Do your final washing of your cleaned copper board with distilled water.
6. A brief etch before your final washing step is essential to give the proper "tooth" for toner transfer.
7. Preheat the copper to 150 degrees or so before the transfer to minimize any heat sinking effects.
8. Rub an ice cube over the back of the transfer sheet before separating it from the pc board.

Fig. 4 – HERE'S AN UPDATE on the direct toner printed circuit prototypes we first looked at in the December 89 issue.

ALARM & SECURITY RESOURCES

Ademco 165 Eileen Way Syosset, NY 11791 (800) 645-7492	Cain Security Systems 2593 Wexbayne Rd, S301 Sewickley, PA 15143 (412) 934-1000	Security Dealer 210 Crossways Park Drive Woodbury, NY 11797 (516) 496-8000
Alarm Installer & Dealer 2512 Artesia Boulevard Redondo Beach, CA 90278 (213) 376-8788	Jensen Tools 7815 South 46th Street Phoenix, AZ 85044 (602) 968-6231	Security Distributing 1350 E Touhy Avenue Des Plaines, IL 60017 (312) 390-2117
ARIUS 959 Concord Street Framingham, MA 01701 (800) 241-3278	King Alarm 145 English Street Hackensack, NJ 07601 (800) 526-0162	Valley Security PO Drawer J Thatcher, AZ 85552 (602) 428-2142

dramatically raises its resistance well beyond 1 Megohm whenever it gets wet. Thus, your sensor is typically at 10K when dry and 1 Meg when wet. A good decision point is to split up the difference on a log basis, and do your tripping at a 100K level.

Figure five shows you one possible sensing circuit. Because you have to keep the total system power under two milliwatts, the maximum dc voltage you are allowed to apply is only 0.8 volts. The sensor acts as a current robber. At low humidities, the sensor's resistance is around 10K and steals so much current, that the NPN transistor remains off. When wet, the sensor impedance goes above a megohm, and conventional current flows into the base of the NPN transistor, turning it on and dropping its output voltage.

The base-emitter junction of the transistor guarantees that the sensor voltage should never exceed 0.6 volts. This is an example of a *current steering* mode of operation.

That inverting CMOS *Schmidt* trigger gives you an on-off snap action. Your red light emitting diode lights when wet and the green when dry.

You do have to be fairly careful with these. Fingerprints, solvents, or even ions from your city water can damage the sensor, as can organic chemicals from certain mounting adhesives. Solder flux and flux removers are also a no-no.

Once again, your highest permitted applied voltage is only 0.8. Any self-heating is not allowed.

There are a number of other dew sensors. Some of these work only under ac drive, and others may have different impedance levels. Be sure to have the data sheet for your actual device on hand if you try to use any of these alternates.

Tellyawhat. For this month's contest, just tell me about a new or unique use for dew sensors. There will be all of those usual *Incredible Secret Money Machine* book prizes going to the best

dozen or so entries, with an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two for the best of all.

As usual, all entries must be written and should be sent directly to me here at *Synergetics*, rather than on over to **Radio-Electronics** editorial. Show me what you can come up with on this.

New Tech Literature

Data books this month include the *Data Conversion Products Databook* from *Analog Devices*, and an absolutely astounding new *Semiconductor Product Guide* from *Samsung*. This latter gem is chock full of new hacker integrated circuits for use as scientific calculators, speech synthesis, melody chips, cassette recorders, watches, for alarm clocks, and bunches more.

Two surplus catalogs are available from *R&D Electronics* and *Lehman Scientific*. R&D is heavy into low cost stepper motor bargains, while *Lehman* has weather radiosonde transducers that include humidity, pressure, and temperature sensing for only \$3.50. The stock number is MC-1019-MOD.

Some surprisingly cheap and high quality digital voice recording and playback modules are available from *Ming Engineering*. The single quantity prices start at \$49. These are all fully EPROM programmable. They seem to use that new *Toshiba* TC8830F speech synthesis chip.

Car Audio is an interesting slick magazine for high power mobile music buffs.

American Design Components has a new surplus catalog that includes \$14 ultrasonic radars and \$15 gyroscopes, among scads of other goodies. And *Chips and Technologies* has a new 82C235 single-chip AT motherboard out, along with a free data book.

Turning to mechanical stuff, low cost nylon bearings and a free calculator are available from *Thompson Nyloner*, while the *IGUS* folks offer all sorts of self-lubricating plastic bearings. The prices start at fifteen cents in quantity.

A reminder here that I am book-on-demand publishing a complete set of the edited, indexed, and updated reprints of everything you've seen here in these columns since day one. Ask for my *Hardware Hacker*, volume II, now available through *Synergetics*.

I also have an *Intro to PostScript* VHS video. Let's hear from you. ♦

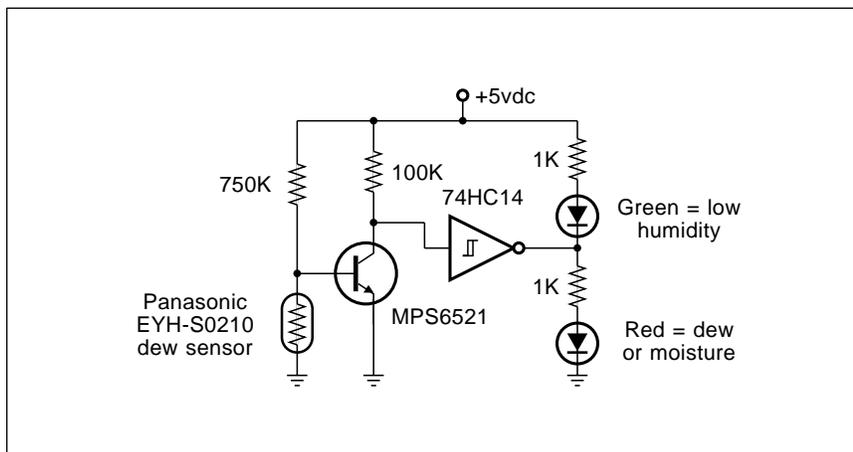


Fig. 5 – A DEW SENSOR TEST CIRCUIT. The red LED lights when the humidity exceeds 100 percent; the green one turns on in the absence of dew.

This month, I figured we'd look at a rather mis-named integrated circuit that has an unbelievable future hacker potential. But first, as usual, let's pick up some background...

A Programmable Analog Inverter

Figure one shows my favorite "sleeper" circuit found in my *CMOS Cookbook*. This is a single-ended and simple op-amp circuit that gives you a choice of a +1 or -1 gain under manual or electronic control.

You can analyze most any op-amp circuit by treating the (-) and (+) input sources separately. By a fundamental electronic law known as *superposition*, you can get a combined final result.

Assume that we have a fairly low impedance input source which also provides a resistive path to ground. Suppose we close the switch. The (+) input sees only the resistor to ground. The (-) input acts as an amplifier with a gain of -1, since the input resistor and the feedback one are identical.

As with any op-amp, the (-) input can be treated as a *virtual ground*, since any deviation from the grounded (-) input will cause an output change that reaches back around through the feedback resistor to continually seek a zero difference between the (+) and (-) op-amp inputs.

What if we open the switch? Well, we still have one input signal along the top that still has a gain of -1. But now there's a new input signal path along the bottom, which has a gain of +2. Because of the feedback action, the (-) input of a properly connected op-amp will be a virtual ground "short circuit", while the (+) input will be a high impedance "open circuit".

Hmmm. The gain along the top is (-1). The gain along the bottom is +2. And, the last time I checked, $(-1) + (+2) = +1$. So, close that switch and you'll get a gain of -1. Open the switch and you get a gain of +1. Presto. A programmable linear inverter.

Your switch can be a manual one, or else a high speed electronic one. A

quarter of a CMOS 4066 is often an ideal choice for this sort of thing.

As we will shortly see, there are zillions of uses for this circuit. One obvious place is as a *video inverter*, used to create negative video images for special needs. To create a video inverter, you take this circuit and add a sync separator, such as the *National LM1881*, and set things up to invert only your video portions but not the sync portions. Naturally, a video-quality op-amp would be needed for this use. Additional bias current can be switched in as needed to get the correct signal levels.

But, we'll save that for some other time, because what I really want to get into here are the secrets behind...

Synchronous Demodulation

The switch in figure one could be turned off and on at very slow rates compared to your input signal frequency. Or at equal rates. Or even at much higher rates. Now, if you turn the switch on and off at precisely the same speed as your input signal, you create a beastie known as a *synchronous demodulator*.

Synchronous demodulators form a super-important electronic concept used just about everywhere. A sync demod's name can change all over the place, being otherwise known as an *autocorrellator*, a *lock-in amplifier*, a

doubly balanced modulator, a *phase-sensitive detector*, *I-Q demodulator*, *synchronous rectifier*, a *phase-locker*, or, going back to some really ancient history, as a *homodyne detector*.

Figure one can also be used as a modern and handy sync demod circuit. What is especially nice is that this is a single-ended circuit which needs no transformers of any kind.

In general, any sync demod is an electronic multiplier that extracts the *sum* and the *difference* between your input frequency signal and your reference switching frequency.

For instance, figure two shows you what happens if we keep the input and switching frequencies identical, but shift their phases. Let's first assume a zero phase difference between signal and reference.

The amplifier's gain will be (+1) for the positive signal peaks, and (-1) for the negative signal peaks, giving us a plain old full wave rectifier. The "dc term" here will be a direct current level equal to the strength or amplitude of the input signal. The "lumps" will be a double-frequency and higher "ac term" that is usually filtered out.

Thus, the zero phased synchronous demodulation should extract only the *amplitude* of an input signal.

Suppose we next shift the phase by 180 degrees. This time, your gain is (-1) for the positive lumps and (+1) for

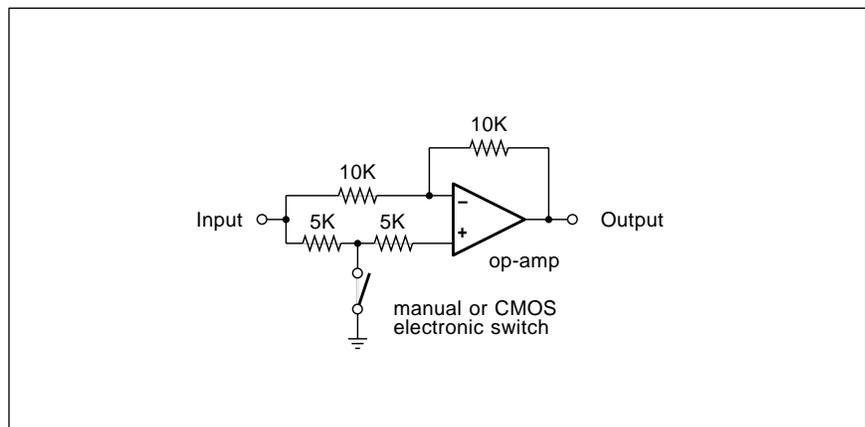


Fig. 1 – A PROGRAMMABLE GAIN AMPLIFIER. When the switch is closed, the gain is -1. When the switch is opened, the gain is +1. One important circuit use is for full wave synchronous demodulation.

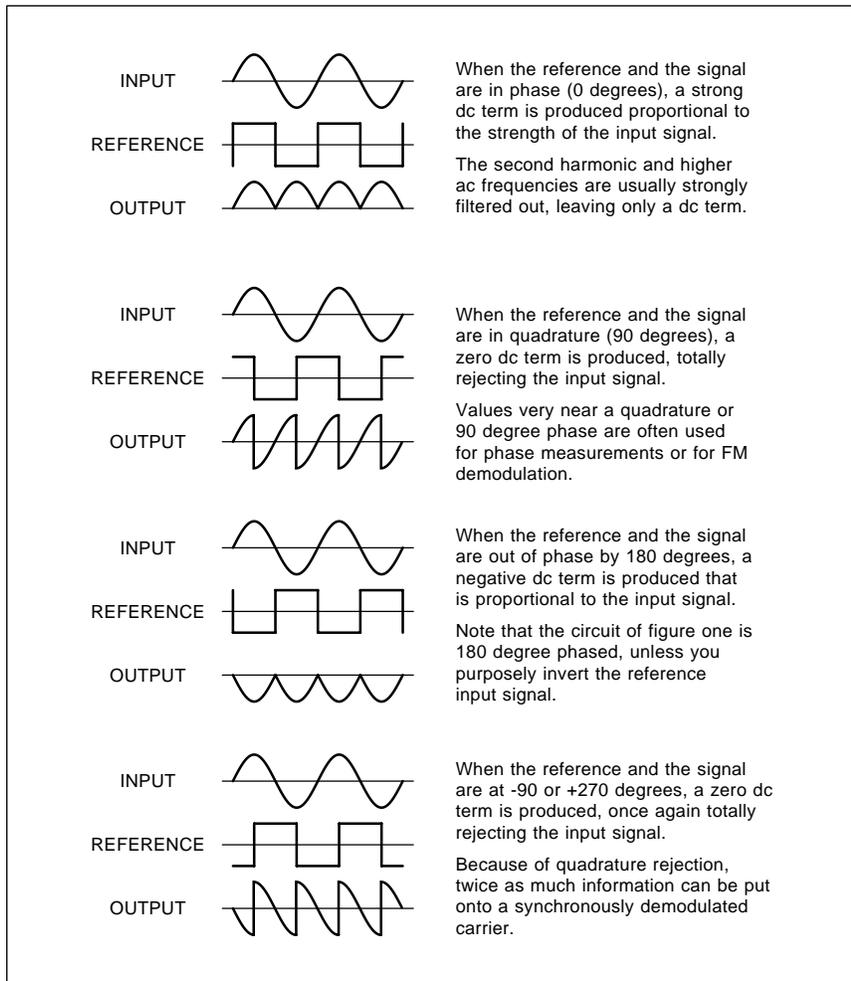


Fig. 2 – SYNCHRONOUS DEMODULATOR WAVEFORMS. At 0 degrees reference phasing, the "dc" portion of the output is proportional to the input amplitude, and interfering signals are strongly rejected. At 90 degrees, the "dc" portion is zero, and the input signal itself gets strongly rejected.

the negative lumps of the signal. We get a *negative output*, and we could conclude that any 180 degree phased synchronous demodulation extracts only the *negative of the amplitude* of the input signal.

Now, let's get interesting. Suppose we shift the phase to 90 degrees. What happens? Well, *nothing at all*. During the time the switch is closed, we have half of a positive cycle and half of a negative cycle, so our net (or average) dc output is *zero*. Very handily, any synchronous demodulation at a 90 degree phasing produces a *zero* output. And, since nothing upside down is still nothing, a similar cancellation happens at -90 or +270 degrees.

But wait a minute. If we get zero output at a 90 degree phase, can't we

double the information placed on a carrier, simply by having an in-phase term and a 90 degree, or *quadrature* term? We sure can, and it gets done all the time.

For instance, the color information on an NTSC (Never The Same Color) television is placed onto a magic sub-carrier of 3.57545 Megahertz. The *hue* of the color is the *phase angle*, while the *saturation* of the color sets your amplitude. At the receiver, a *phase-lock loop* does an in-phase "I" and a quadrature "Q" demodulation. After further processing, all the separate amplitudes are extracted for the red, blue, and green guns in the display tube. Thus, we have used a pair of synchronous demodulators to extract both the amplitude and phase of a

complex signal at the same time.

Let's look at some additional uses for synchronous demodulation. If you hard limit the input signal to your sync demod so it is a clean square wave, then you will provide *phase detection*. Go through the math, and you will find that your output voltage is a triangle which linearly equals the phase angle between the input and the reference. You can then use your sync demod to measure the phase angle between two input signals.

Suppose we would synchronously demodulate one signal and at the same time apply an interfering signal of a different frequency. Your "wanted" signal will always be in phase and will always produce a dc output equal to its amplitude. The "unwanted" signal will create a sinewave as it "slips cycles" with respect to the wanted one. Any sinewave averages to zero over a long enough time. We apparently have a way of detecting one signal while we reject an interfering one.

Certain types of sync demods are called *lock-in amplifiers*. These can form an extremely narrow *bandpass filter* that automatically centers on the frequency of interest, and can yield tremendous improvements in signal to noise ratios.

As an example, it is not unknown for your lock-in amplifier to cleanly extract a signal that is buried in noise that can be as much as 120 decibels *stronger* than the signal you want. Important uses here include extracting data from deep space probes, and performing laboratory and medical instrumentation that measures very weak signals in the presence of much larger interfering noise and ac hum.

A not-quite synchronous demodulation will output a sinewave equal to the *difference* between the reference and input frequencies. This is a simple example of a *downconverting*, or *mixing* of one signal against another to get a frequency difference.

By using a pair of sync demods, you can not only extract the frequency difference, but also determine *which* of the frequencies are higher.

The doppler signal extraction in a side-looking radar is one major use. Separately, synchronously demodulating a shaft encoder can give you both speed and direction information. Flangers for electronic music synth-

isizers use a similar principle.

For a really strange use of a sync demod, high power rectifiers always have a forward drop associated with them of a volt or more that can cause all sorts of inefficiencies, especially with low voltage solar panel power conversions. But power transistors can have significantly lower forward drops if they are properly overdriven as a switch. To improve the efficiency of a solar power conversion system, you create a *synchronous rectifier* that uses a sync demod and a pair of power transistors to replace your inefficient power diodes normally used.

Finally, one early way of detecting an am radio station was known as a *homodyne detection*. Here you would synchronously demodulate your incoming signal against a reference of the same frequency as the transmitter carrier and then directly extract your audio in a single step. Unfortunately, these howled a lot as they were tuned and tended towards instability, so they were flushed in the late 1920's in favor of *superheterodyne* circuits that used intermediate frequency amplification, often at 455 Kilohertz. Today, the old homodyne deserves a fresh new look, especially when combined with digital synthesis, and the ability to put highly stable audio gain and good filtering into very small packages.

So, sync demods are easy to build and can be amazingly versatile. But, before we explore a great sync demod chip and more real-world uses, let's briefly look at some little-used hacker components known as...

LVDT's

An LVDT, or a *Linear Voltage Differential Transformer* is shown in figure three. This is a transformer which has a moveable core, a single winding on the primary, and a pair of secondary windings. The secondary windings are connected in *opposition*, so that the output voltage will be the *difference* between the two.

When the moveable core is in the center, equal and opposite voltages are induced in the secondaries, and the output voltage is zero. As your core moves up, a 0 degree phased sinewave appears in your output. As it moves down, a 180 degree phased sinewave appears instead.

With careful design, you can get a

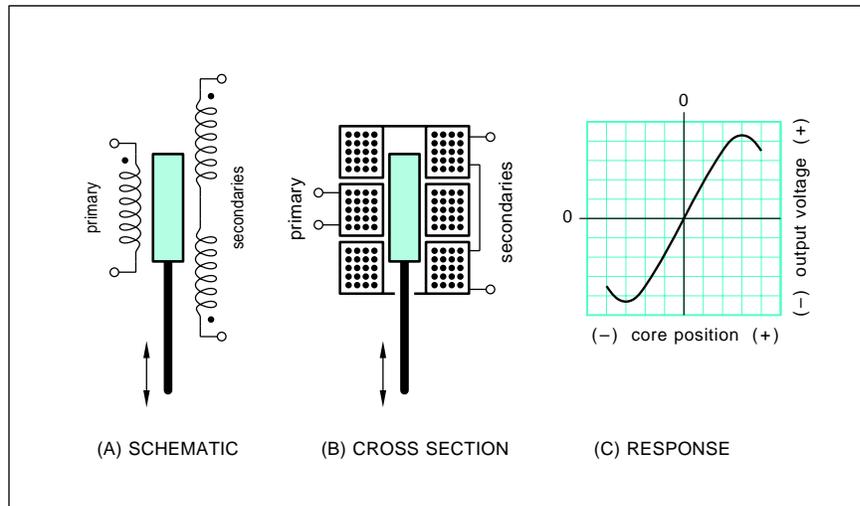


Fig. 3 – LINEAR VARIABLE DIFFERENTIAL TRANSFORMERS, short for LVDT's, can be used for extremely precise position-to-voltage transducers. The output voltage follows the core position. Microweighing is one use.

linear sinewave output voltage whose amplitude changes with position, and whose phase is (0) degrees for positions above center and (180) degrees for positions below center.

In short, a LVDT is a very precise and ultra-sensitive *position to voltage transducer*. Some LVDT devices can easily sense any motions or position changes as small as a thousandth of an inch or less. They can also be made large enough to measure distances of several feet or more.

Unfortunately for hackers, LVDT's are rather pricey, since they are both low-volume and precision components. One useful surplus source is *AST Servo*, while others advertise in the *Sensors and Measurement and Control* trade journals.

Several LVDT uses? Weigh scales, especially for microweighing. Torque sensing. Accelerometers. Distance measurement. Inclinometers. Pressure transducers. For seismometry. Load cells. Micropositioners. Or anywhere else you want to convert a very small motion or distance change into a useful electrical signal.

For precision results, your LVDT must get driven from a pure audio sinewave of a fixed and known amplitude. Distortion could lead to bad harmonics which will in turn create output errors and other difficulties.

To further up the LVDT precision, you can use a LVDT in its *servo mode*. Here, you'd use feedback to move,

balance, shove, or otherwise continually coerce the *LVDT* back to its null position. This is known as *null seeking*, and, because of the feedback, many non-linearities can be greatly reduced if not cancelled outright.

While LVDT's are usually super-precise, there's no reason you can't throw one together on your own to create a low cost position sensor. Be sure to let me know what you do come up with on this.

By another of those astounding coincidences that infest this column, it looks like we need a sync demod to extract the position info from a LVDT. But, if we have a simple and cheap circuit that does this, why limit it to LVDT uses, when so much more can be done so much better with it?

Which brings us around to...

The Misnamed Chip

Sometimes a manufacturer might simply put the wrong name on one of their integrated circuit chips. For instance, which of these two has the greater hacker potential – a *Signetics* NE5520N LVDT Signal Conditioner, or a *Philips* NE5520N Universal Single Chip Treasure Finder?

As you might guess, *Signetics* is *Philips*, and, of course, the NE5520N is the NE5520N.

Figure four shows details. What we have is a precise amplitude and low distortion audio sinewave generator, a synchronous demodulator, and one

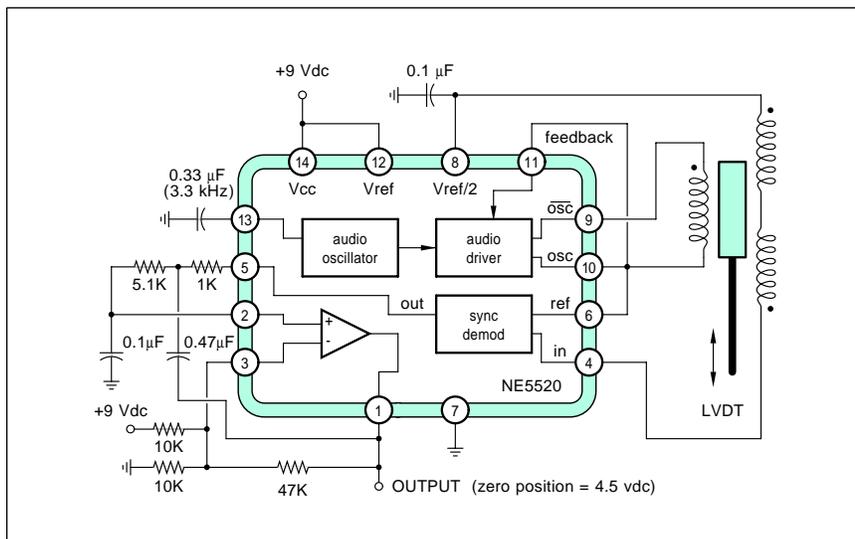


Fig. 4 – THE PHILLIPS/SIGNETICS NE5520N has an internal precision sinewave generator, a sync demod, and an extra op-amp that gets used here as an output filter. This is how to apply it as an LVDT signal conditioner. Since this chip can do so much more, it does seem a shame to waste it on LVDT uses.

uncommitted op-amp you can use for output filtering, meter driving, or in-phase to quadrature conversions. The circuit shows you how to power and sense the output of a LVDT.

While you actually could use one of these chips with a LVDT, the beast should work well for an extremely wide variety of hacker stuff. Where else could we use an audio source and

a sync demod?

One place could include modulated infrared alarms and communicators that can ignore both sunlight and room lighting. A second might be in the fluxgate magnetometer used in solid state digital compasses.

How about treasure finding? I can think of at least a dozen uses here. Figure five shows us how the search

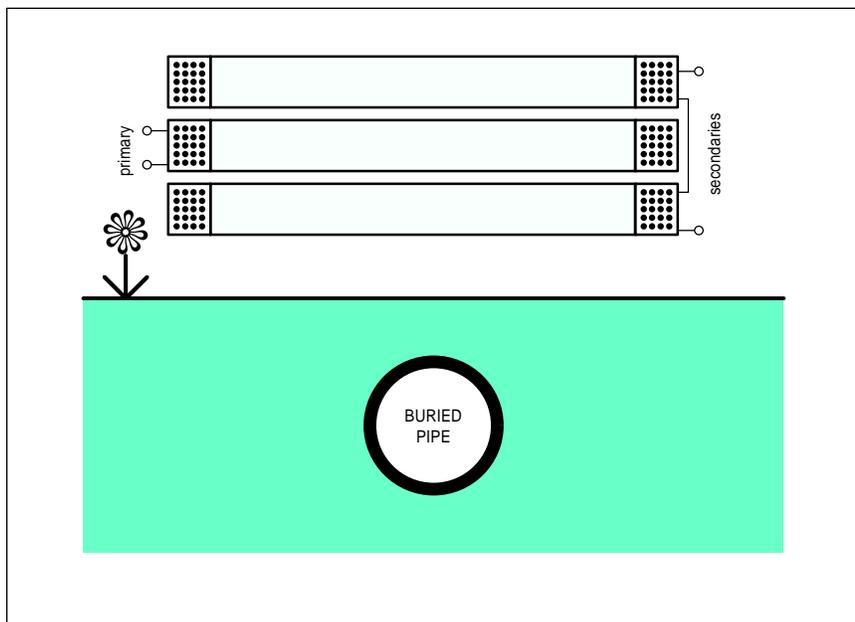


Fig. 5 – THE SENSING HEAD of an induction-balance treasure finder or a metal locator can be thought of as an LVDT in disguise. The target acts as a moveable core. Synchronous demodulation can separate metal from mineral detection.

head of an induction balance metal locator is really a LVDT in disguise.

In the absence of a buried object, the voltages induced into the output sensing coils are equal and opposite. A buried ore or a metal object will distort the transmitted field, and unbalance the output voltages.

Now for the neat part. Any "metal" objects return an in-phase component to the output signal, while "mineral" deposits, such as a well rusted can, return us a quadrature signal. Nicely separating the goodies from all the grunge and garbage.

Thus, the NE5520N circuit can be used for in-phase discrimination of metal objects, or for quadrature discrimination of mineral objects.

To do the quadrature synchronous demodulation, just shift the phase of your reference by 90 degrees. Add a second NE5520N, and you can also add such advanced features as automatic ground tracking and the "native" soil background cancellation effects featured on higher priced locators.

Similarly, over in those receiver-transmitter styles of metal locators often chosen for pipe finding, fiber optics can be used to optically couple from the transmitter to the receiver, minimizing any field distortions an actual cable might create. A sync demod at the receiver could then be used for improved sensitivity and for metal/mineral discrimination.

The NE5520N costs around \$7 in smaller quantities. Supply current is around seven milliamperes, easily provided by a nine volt battery. While you can run the chip at +5 volts, its stability will not be as good.

For additional NE5520N circuit details and bunches of applications info, see the *Industrial Linear Data Manual II* offered by Philips. Check out the newer NE5521N as well.

Printing Resources

As you know, each month I try to feature a *Resources Sidebar* which shows you where to go for the real insider stuff on unusual subjects of hardware hacking interest. Sources that are difficult or impossible to quickly pin down on your own. Be sure to tell me what you want to see in future sidebars.

This month's sidebar gives you a rundown of the major sources of

information on printing and print-shops. What does this have to do with hardware hacking? Just this – There's a total desktop publishing revolution going on out there, and traditional printing equipment and machinery is so utterly and outrageously priced that it simply won't hack it.

What we need instead is for all you hackers to come up with low cost and low-end, do-it-yourself hardware kit solutions for new desktop printing and book-on-demand publishing needs. To do this, hacking skills and a hacker mentality are essential. And the opportunities are pretty nigh unlimited.

What's needed? Well, for openers, here's a tiny part of my wish list...

(1) A low cost *Kroy Kolor* machine that doubles as a laminator and as a printed circuit direct-toner transfer processor.

(2) A true perfect binder that gives fully professional cold-glue results for under \$99.

(3) A sanely priced clamping paper cutter which can accurately trim 200 sheets at a time.

(4) A die punch that in one whomp cuts out twelve business cards from a single sheet of cover stock.

(5) A low cost padding press.

(6) An economical and programmable folder.

(7) A simple-to-use pad printer for the "real" printing of pens, golf balls, mugs, keyholders, and such.

(8) A cheap corner rounder.

(9) A workable paper drill.

(10) Automated conversions from a laser printed image onto T-Shirts, for rubber stamps, and for CAD/CAM machining of a plastic mockup or even actual hardware.

(11) A super scungy vacuum packer and/or shrink wrapper.

(12) A method to convert an orbital jitter sander into a paper jogger.

(13) A new combination scoring, perforating, and die-cutting machine, possibly with a hot foil die-stamping capability as well.

(14) A very low cost power stapler strong enough to handle *Jiffy Bags*.

(15) Solutions to economical custom glass etching.

(16) Vinyl hot-knife sign cutters and PostScript driven wood and/or aluminum routers.

Once again, your projected final

PRINTING RESOURCES

American Printer
29 N Wacker Drive
Chicago, IL 60606
(312) 726-2802

Font & Function
PO Box 7900
Mountain View, CA 94039
(800) 833-6687

Graphic Arts Monthly
249 W 17th Street
New York City, NY 10011
(212) 463-6834

Graphic Arts Prod. News
29 North Wacker Drive
Chicago, IL 60606
(312) 726-2802

High Volume Printing
Box 368
Northbrook IL, 60065
(312) 564-5940

In-Plant Printer
Box 368
Northbrook, IL 60065
(312) 564-5940

In Plant Reproductions
401 North Broad Street
Philadelphia, PA 19108
(215) 238-5300

Instant Printer
Box 368
Northbrook, IL 60065
(312) 564-5940

Print Equipment News
Box 5540
Glendale, CA 91221
(818) 954-9495

The Printers Shopper
PO Drawer 1056
Chula Vista, CA 92012
(800) 854-2911

Printing Impressions
401 North Broad Street
Philadelphia, PA 19108
(215) 238-5300

Printing Journal
Box 91447
Pasadena, CA 91109
(818) 793-7901

Printing News
245 W 17th Street
New York City, NY 10011
(212) 463-6727

Publishing Technology
401 North Broad Street
Philadelphia, PA 19108
(215) 238-5300

Quick Printing
1680 SW Bayshore Blvd
Port St Lucie, FL 34984
(407) 879-6666

Screen Printing
407 Gilbert Avenue
Cincinnati, OH 45202
(513) 421-2050

Type World
15 Oakridge Circle
Wilmington, MA 01887
(617) 658-6876

U&Ic
2 Dag Hammarskjold Plaza
New York, NY 10017
(212) 371-0699

cost to the end user on any and all of these should end up in the \$25 to \$99 range, or under *one-tenth* of the sales commissions of the "real" print machinery that all this stuff is inevitably going to shoot out of the saddle.

Your hacker abilities are obviously needed to hold all the costs down. And lots of electronics and power control does seem to be involved. This is one hot topic right now, with a potential market in the millions of units.

Two Contests

Let us have two contests for this month. As usual, there will be an *Incredible Secret Money Machine* for the dozen or so best entries, with an all-expense paid (FOB Thatcher, AZ) *tinaja quest* for two awarded to the very best of all.

Either (A) show to me a new and unique hacker circuit involving the NE5520N with some unusual synchronous demodulation use, or else (B) show me a low-cost solution to some desktop publishing peripheral hardware of one sort or another.

New Tech Literature

Those *Philips* folks have recently bought out *Amperex* and several other companies. They've now released a

wheelbarrow full of fat, new, and free data books. Check out their *Light Emitting Diode; RF Power Transistor; High-Voltage Transistor; RF Power Module; Thyristor; Small Signal Transistor; Surface Mounted Semiconductor*; and the *PowerMOS* data books for openers. There's bunches more where these came from.

Linear Technology has issued a great new 1990 *Linear Data Book* that is crammed full of great hacker integrated circuits.

Free software this month includes the latest *Specs in Secs Discrete Data* from *Motorola*, and the *PCBII* printed circuit layout demo from *OrCAD*. And unusual free samples for this month include the MC33034 *Brushless Motor Controller*, again from *Motorola*, the *Advanced Bus Interface Product Samples* from *Texas Instruments*, and the various low cost jellybean integrated circuits from *Calogic*.

Our reminder here that *Midnight Engineering* is a great new hacker magazine aimed at all small-scale hardware and software productions. Free samples are available.

Rounding out the selections, the *Chomerics* folks have a new *Cho-Flex 440-X* line of force sensitive inks.

Let's hear from you ♦

Don Lancaster's Hardware Hacker

April, 1990

Organic Vapor Detectors
Low Melting Point Alloys
Ultraviolet Flame Detector
Alternate Energy Resources
Five Band Equalizer Circuit

We appear to have a really mixed bag of outstanding goodies for this month, so let's just jump right in. As usual, please do note that all of our referenced sources appear in either the alternate energy resource sidebar or in the names and numbers appendix...

Hazardous Materials

I've gotten several calls asking how to dispose of any spent printed circuit etchant. Since I'm part of the Haz-Mat team at our local fire department, I thought we'd look at the big picture first. Back to square one.

We can define a *hazardous material* as any substance that is out to do you in. It might burn, explode, be chemically reactive, be biologically active, poisonous, radioactive, or might interact violently with water or air.

As a hardware hacker, you probably expose yourself to hundreds of hazardous materials. Knowing ahead of time what these nasties are and what they can do to you is common sense.

Most industrial chemicals and by-products have to provide a *Materials Safety Data Sheet*. Obviously, you'll want to read and collect these. If you have any employees, you are required by law to make any relevant sheets available to them on request.

Unfortunately, most MSDS listings do a total whitewash job and dwell on stupid trivia. For instance, the sheet on Kapton films goes out of its way to tell you that these films are slippery and you can trip on them if you leave them on the floor. But they make no obvious mention that Kapton turns from an insulator into a conductor above a certain temperature, totally trashing any computer or electronic system it is involved with. Always watch for understatement, weasel words, and any misdirection when you are reading these sheets.

One of the best Haz-Mat references is the "yellow" book from DOT, and otherwise known as the *Emergency Response Guidebook*. This lists most industrial chemicals and tells competent professionals how to deal with

them under emergency conditions.

Single copies are obtainable at no charge on request.

A second resource is the 24-hour emergency telephone number from *Chemtrec* at (800) 424-9300. This is a free chemical industry service that can instantly place you in contact with experts on any hazardous material. But note this is an emergency response number, sort of a nationwide 911. Do not use it for idle chat.

An interesting free trade journal that deals with all hazardous materials is *Pollution Equipment News*. This one also exposes you to some real pneumatic and electronic gems that you might not otherwise see.

Naturally, any genuine Haz-Mat incident should be handled by the professionals, usually contacted with your nearby 911 number. One of the hardest things for the pros to learn are that their preconditioned "Save my Baby!" super-aggressive initial fire attack strategy is most often dead wrong in a Haz-Mat incident. Doing nothing at all is usually far better than becoming part of the problem.

The quantity of the material and the way you store it will also make a big difference. Common sense is an obvious factor here.

In the case of ammonium persulfate printed circuit etchant, storage of the dry etchant in small and sealed plastic containers is recommended. *Tupperware* works quite well for this. Some ammonium persulfate etchants also include a highly poisonous mercury activator. So, you never work in your kitchen, always be in a well ventilated area, and always wear safety glasses and plastic gloves.

Note that ammonium persulfate is an oxidizer. If you do use a wooden spoon to stir it, and come back a week or two later, chances are you'll have nothing but a burned-off spoon handle left. Do avoid all contacts between ammonium persulfate and any organic materials.

Now, don't tell EPA I told you this, but you can simply flush spent ammonium persulfate etchant solution

down the drain if (A) you are on a city sewer system, (B) you dilute it with great heaping bunches of *very cold* water, and (C) you are doing this with less than two quarts of etchant each week. Do note that your ammonium persulfate is intended for dissolving copper and your sink drain trap is usually made from copper or a copper alloy. Hot and concentrated etchant here is obviously a no-no.

Low Temperature Alloys

I just got a new copy of *Catalog #12* from *Small Parts*. As we've seen a time or two in the past, these folks are a great source for everything your hardware store never heard of, besides custom cutting small quantities of metal and plastics for you.

Several of their more interesting products include a series of four low temperature melting alloys. Figure one sums up their properties.

The melting points for these alloys are set to 117 degrees Fahrenheit, 158 degrees, 255 degrees, and 281 degrees. They are available in quarter and one pound sizes, and range in price from

LMA-117

Melts at 117 Degrees Fahrenheit.
Contracts slightly on cooling.
About \$7.50 per ounce.

LMA-158

Melts at 158 Degrees Fahrenheit.
Expands slightly on cooling,
About \$1.35 per ounce.

LMA-255

Melts at 255 Degrees Fahrenheit.
Expands slightly on cooling.
About \$1.00 per ounce.

LMA-281

Melts at 281 Degrees Fahrenheit.
Expands slightly on cooling.
About \$2.20 per ounce.

Fig. 1 – LOW TEMPERATURE alloys you can get through *Small Parts*. Two of these can be melted and cast with boiling water. What hacker uses can you think of?

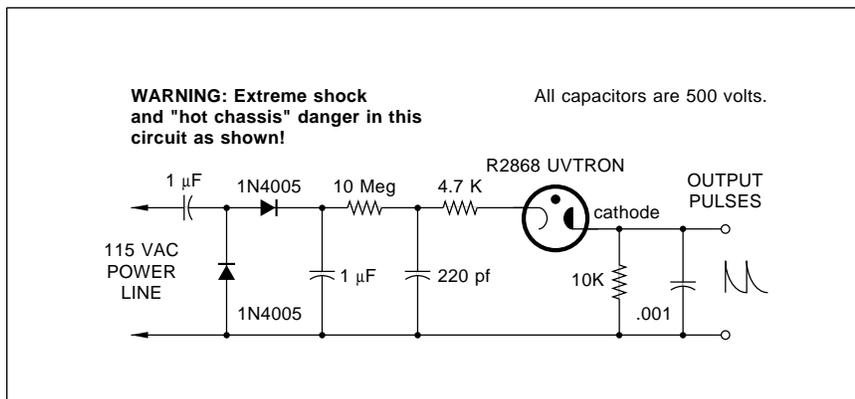


Fig. 2 – AN ULTRA-VIOLET FLAME SENSOR. The circuit is basically a neon lamp relaxation oscillator. Its frequency is a few counts per minute in the absence of a flame, and a mid to high audio frequency with a flame present.

\$28 to \$78 per pound. Unfortunately, the 117 degree one is by far the most expensive, since it is around one-fifth indium, a precious metal.

Those two alloys with the lowest melting point can easily be cast from a "crucible" placed inside boiling water on your stove. Plaster or silicon rubber molds should work just fine.

While you could, in theory, mix the alloys together to get different melting points, it pays to know what you are

doing. Otherwise, instead of a free flowing *eutetic* liquid, you might end up with so much dross.

I can think of all sorts of unusual and off-the-wall uses for these, but why don't you tell me instead? As our contest this month, just dream up a unique application for a low melting point alloy. There'll be all the usual *Incredible Secret Money Machine* book prizes, along with an all-expense paid (FOB Thatcher, AZ) *tinaja quest* for two for the best entry of all.

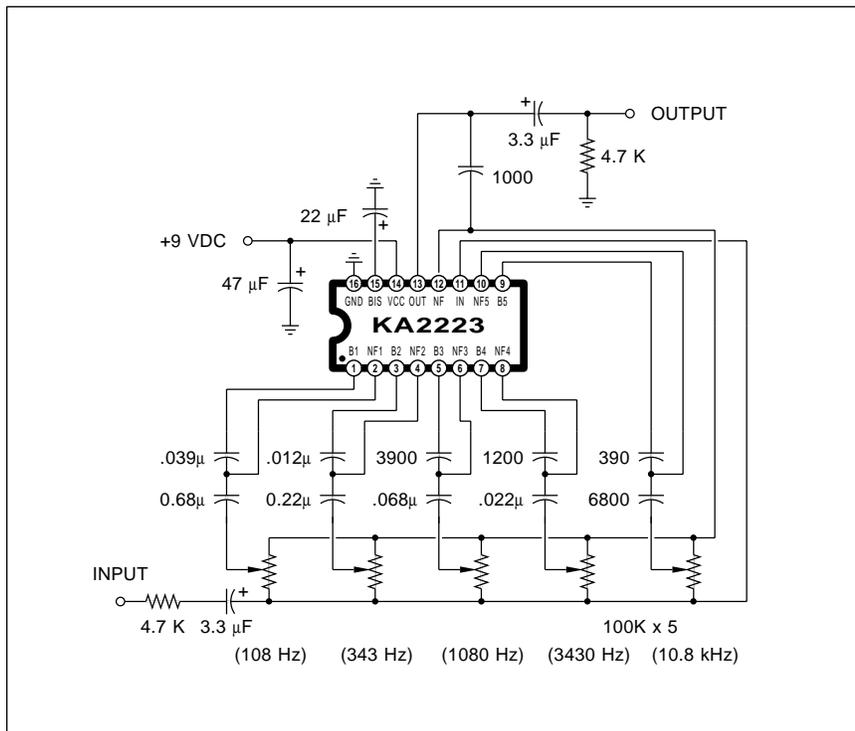


Fig. 3 – A 5-BAND GRAPHIC EQUALIZER that uses a single Samsung integrated circuit. A pair of chips can be used for ten bands.

Please be sure to send your written entries directly to me and not over to **Radio-Electronics** editorial.

A Flame Detector

At one time way back when, far and away the numero uno hacker component was the NE-2 neon lamp. It was incredible what you could do with these. For panel lamps, night lights, polarity detectors, spike protectors, winking oscillators, tiny disco stars, tone generators for electronic organs, vacuum tube filament checkers, hot chassis ac checkers, triggers, voltage regulators, and bunches more.

Sadly, the good old ten cent neon lamp isn't even on most hacker charts any more, done in by its need for high voltage, and its limited brightness and color range. Sigh.

But the *Hamamatsu* folks have come up with an interesting variation on the traditional neon lamp. It is the *UVTRON R2868* flame sensor.

Figure two shows you a typical circuit. Any open flame has lots of ultraviolet energy associated with it. This circuit is a simple relaxation oscillator. In the absence of strong ultraviolet energy, the oscillator only fires every few seconds or so. When sensing the oscillator fires as much as 5000 times a second. Thus, you get an audio tone out in the presence of the ultraviolet energy from a flame, and only a few random clicks otherwise.

This is sensitive enough to easily detect a match at 10 feet. While the recommended supply voltage should be within ten percent of 325 volts, you can usually work with the simple line-operated voltage doubler shown.

Note that this is a "hot chassis" type of circuit with a severe shock hazard potential. You'll probably want to use an optocoupler on the output in your final circuit, and an input isolation transformer would also be a good idea. The output pulses are normally around eight volts high and about five microseconds wide.

Two use tips. Be certain the anode resistor is physically rather close to your flame sensor. And avoid having two sensors near each other, since they produce ultraviolet in use and could badly interact or even latch.

Hamamatsu also makes small and complete flame sensor circuit cards ready for use that run off the usual 24

volt ac thermostat transformer. While intended for flame detection in gas heaters and in air conditioners, there should be plenty of other interesting hacker uses. What can you come up with here?

A Great New Data Book

I've seen some exciting data books before, but this one is way off the scale. It reads like a pulp novel that you literally cannot put down. Each and every page is crammed full of outstanding new low cost hacker integrated circuits that cry to be used. We could spend years of hardware hacking columns and never leave this single great book.

I am referring to the new *Linear IC Volume 1* data book by *Samsung*. This beauty is crammed to the gills with audio, video, and remote control toy radio chips. All sanely priced, and all with detailed application examples.

As a random example, let's drop in on page 178 where we see a single chip 5-band graphic equalizer. Full details appear in figure three.

While this is a five band equalizer, you can easily use a pair of chips for a ten-bander, again per their data book. Only a volume control and a pair of capacitors are needed per band.

Other goodies in the book include audio power amplifiers and preamps, the complete toy R/C vehicle remote drivers, infra-red encoders and preamps, VCR servo controllers, audio cassette-on-a-chip devices, video sync separators, up to a complete *single chip* high quality television circuit!

Have fun with this one.

Fume and Vapor Detectors

There are many reasons why you might like to detect any organic or chemical vapors in the air. In home uses, we have gas leak detection, fuel vapors, carbon monoxide, "stuffy" air ventilation controls, auto microwave oven "the roast is done" sensing, DWI breath alcohol testers, the combustion monitoring, odor detection, and oxygen sensing.

Similarly, in industry sensors are sometimes needed to spot ammonia, hydrogen sulfide, organic vapors, for freon, and other organic vapors.

The people at *Figaro Engineering* have dozens of low cost and easy-to-use sensors, optimized for various

substances. Figure four summarizes many of their key models. Quantity costs are in the \$5 range.

In general, each sensor consists of a sintered block of tin oxide, with variations that will optimize it for any particular sensed vapor.

An internal heater is used to raise the surface temperature to the 200 to 400 degrees Centigrade range.

Through surface adsorption, the resistance of the tin oxide will drop in the presence of an organic vapor. The amount the resistance drops depends on the vapor and its concentration.

For instance, figure five shows you how the TGS822 gets used as a breath alcohol detector. You apply a 5 volt ac or dc heater voltage at a current of 120 milliamperes or so. You apply a main supply voltage of 24 volts ac or dc, and sense an output voltage across a 3.9 K load resistor.

In the presence of 300 parts per million alcohol, the sensor resistance will drop by 10:1. At 3000 parts per million alcohol, the sensor resistance will drop by 50:1. Thus, both the presence and the strength of the organic vapor can be measured. The response time is typically a few seconds.

Full response curves appear on the data sheets and ap-notes available directly from Figaro. Do note that these are relatively broad spectrum devices. They may well respond more strongly to certain other vapors than the one you are actually looking for. Thus, they will work best in those situations where one and only one vapor or contaminant is expected.

Ads for similar sensors often appear in *Pollution Equipment News*. Let me know if you want to see any more details on sensors of this type.

Alternate Energy Resources

Bowseretta and I were recently day hiking over at Antelope Springs, a long-abandoned hippie commune.

Besides the obligatory rusting VW microbus shells, the ruins of dozens of alternate energy experiments seemed strewn about. There were ocatagon earth sheltered houses, a sauna and hot tub combo lovingly crafted from the native stone, the broken *Savonius* windmill rotors, countless cracked batteries, and various solar stills.

At least one of these stills must have been a monumental disaster, since the

evaporator and the condenser were both designed to operate at the same temperature and pressure. Oh well.

I guess an awful lot of dreams died here. Somewhere along the way.

On the other hand, the solar pump factory down the street is bursting at the seams with new activity. It seems a dose of reality has at long last caught up with alternate energy.

The old order fadeth.

So, where does this leave us? What are the key hardware hacker alternate energy resources for the nineties? This month's resource sidebar gives us a clue or two.

The very core of today's alternate energy appears to be a funky little magazine known as *Home Power*. Besides its no-nonsense shirtsleeves tech articles, this gem is full of ads for all

CMS-302	Oxygen combustion sensor. Externally heated to 700-900 C. 12 volt supply.
TGS-100	For fumes and odors in air. 1 volt, 440 milliwatt heater. 100 volt supply.
TGS-109	For natural gas and gasoline. 1 volt, 440 milliwatt heater. 100 volt supply.
TGS-203	For carbon monoxide. 0.8 volt, 700 milliwatt heater. 12 volt supply.
TGS-813	For propane and methane. 5 volt, 830 milliwatt heater. 24 volt supply.
TGS-822	For DWI breath alcohol testers. 5 volt, 830 milliwatt heater. 24 volt supply.
TGS-880	For automatic microwave cooking. 5 volt, 830 milliwatt heater. 24 volt supply.

Fig. 4 – VAPOR DETECTORS from Figaro. Each has been optimized for specific sensing tasks.

Hardware Hacker

the leaders in the field. Cost is around \$6 per year.

Still at the same old stall is the good old *Whole Earth Review*, the ongoing continuation of the original *Whole Earth Catalog* and its progeny. Of the 497 magazines I personally subscribe to, this one is number two, right up there behind *MAD*. Nothing else even comes remotely close. Today the WER folks are heavily into CD ROM distribution and their major alternate lifestyle BBS system widely known as *The Well*.

While both *Mother Earth News* and *Popular Science* have lots of useful alternate energy stuff in them, there is a key difference. PS will admit they have contacted a terminally incurable case of *Yuppus dementus*, while MEN does not.

UPDATE: MEN folded.

I've found that *HVAC News*, a free air conditioning trade journal, also has a surprising amount of the alternate energy stuff in it.

Although most of the other solar and the wind magazines have folded, *Solar Energy* remains as one useful, albeit a highly technical resource. Since subscription costs on this are totally absurd, you'll want to go to a larger tech library to view a copy.

The feds have bunches of alternate energy info available, spread over a dozen agencies. The Department of Energy often sponsors seminars and technical paper presentations. So does the National Bureau of Standards. Try

ALTERNATE ENERGY RESOURCES

<p>Arco Solar PO Box 6032 Carmarillo, CA 93010 (805) 482-6800</p>	<p>Photocomm Inc 930 Idaho Maryland Road Grass Valley, CA 95945 (800) 544-6466</p>	<p>Solarex 1335 Piccard Drive Rockville, MD 20850 (301) 948-0202</p>
<p>Assc Energy Engineers 4025 Pleasantdale S420 Atlanta, GA 30340 (404) 447-5083</p>	<p>Real Goods 966 Mazzone Sreet, #4B Ukiah, Ca 95482 (800) 762-7325</p>	<p>Solec International 12533 Chadron Avenue Hawthorne, CA 90250 (213) 970-0065</p>
<p>Bergey Windpower 2001 Priestley Avenue Norman, OK 73069 (405) 364-4212</p>	<p>Sandia National Labs PO Box 5800 Albuquerque, NM 87185 (505) 844-5678</p>	<p>Solvonics Solar 1100 West Maple Road Troy, MI 48084 (313) 362-4170</p>
<p>Energy Depot 61 Paul Drive San Rafael, CA 94903 (415) 499-1333</p>	<p>Snow Belt Solar 286 Wilson Sreet Amherst, WI 54406 (715) 824-3982</p>	<p>Southwest Windpower PO Box 22178 Flagstaff, AZ 86002 (602) 526-0997</p>
<p>Home Power PO Box 130 Hornbrook, CA 96044 (916) 475-3179</p>	<p>Solar Energy Maxwell House, Fairview Elmsford, NY 10523 (914) 592-7700</p>	<p>Whole Earth Review 27 Gate Five Road Sausalito, CA 94965 (415) 332-1716</p>
<p>HVAC Product News 400 N. Michigan Avenue Chicago, IL 60611 (312) 222-2000</p>	<p>Solar Energy Res. Inst. 1617 Cole Blvd. Golden, CO 80401 (303) 231-1000</p>	<p>Yellow Jacket Solar Box 253 Yellow Jacket, CO 81335 (303) 562-4884</p>
<p>Mother Earth News PO Box 70 Hendersonville, NC 28793 (704) 693-0211</p>	<p>SolarJack 325 East Main Safford, AZ 85546 (602) 428-1092</p>	<p>Zomeworks PO Box 25805 Albuquerque, NM 87125 (505) 242-5354</p>

any large technical library that has a government documents section.

One fed document I've found most useful is the *Stand-Alone Photovoltaic Systems – The Handbook of Recommended Design Practices*. This one is available through *Sandia National Laboratories*.

There are lots of distributors of alternate energy products. One of the largest is *Real Goods*, who also offer a 320 page alternate energy sourcebook for \$6.50. Their competitors include *Photocomm Inc*, the *Energy Depot*, *Yellowjacket Solar* and *Snow Belt Solar*. Get their catalogs.

Two establishment associations that have useful resource availability do include the *Solar Energy Research Institute* and the *Association of Energy Engineers*. Write them for their literature and service lists.

The leading manufacturers of solar panels include *Arco Solar*, *Solarex*, *Solec*, and *Solvonics*. Two windpower sources include *Bergey Windpower* and *Southwest Windpower*.

Finally, two of the alternate energy "good guys" definitely include Steve Baer of *Zomeworks*, who is heavy into solar trackers and energy management; plus Jim Allen of *SolarJack*, who specializes in higher efficiency solar pumps and controllers.

Please let me know what else you think needs added to this list. And be sure to tell me which new resource sidebars you want to see included in

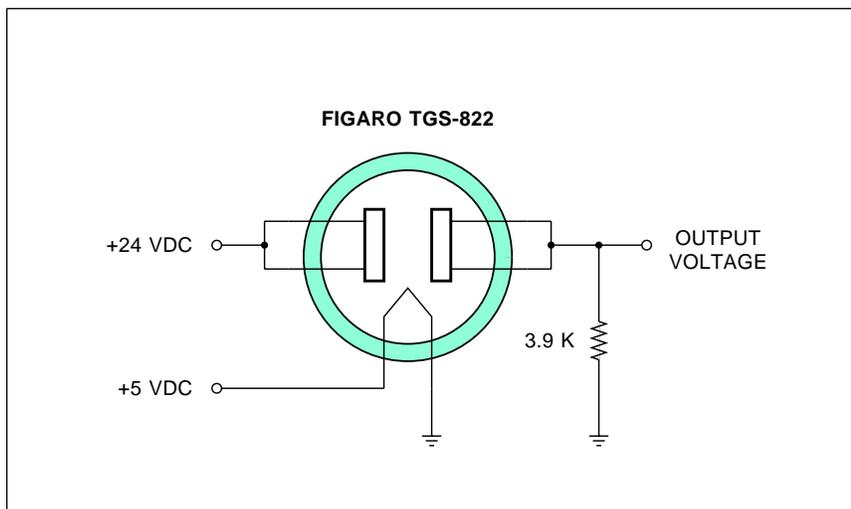


Fig. 5 – A DWI BREATH ALCOHOL TESTER that uses the Figaro TGS-822. The presence of 500 parts per million of grain alcohol lowers the cell resistance by a factor of 10, raising the output voltage.

future issues. ♦

Don Lancaster's Hardware Hacker

May, 1990

Hall Effect Resources
Shape Memory Alloys
Cycolor Printing Secrets
Low Noise Amplification
Unusual Mechanical Stuff

If you ever find out whatever it is we are doing here, please be sure and let me know. At any rate, this month's goodies include a brand new color imaging process, low noise amplifiers, *Hall Effect* devices, and some unusual new non-electronic items that cry out for hacker use.

As usual, please observe that all of our referenced sources do appear in either the upcoming *Hall Effect* resource sidebar or in the *Names and Numbers* appendix. Do check these resources before using our free help line. And please make your product and your literature requests to anyone listed in either sidebar specific, rather than general.

Onward and upward...

The Cycolor Process

Color copiers are getting better and better. While they cannot today challenge the production color printing or photographic processes for cost or clarity, the handwriting is on the wall.

As you might expect, there are now dozens of new color technologies in one stage of development or another. Several of the obvious needs that any color system must meet are accurate color registration, low materials cost, dense resolution, and the ability to faithfully reproduce an original.

One of the candidate systems is called the *Cycolor* process. This one is in volume production, solves most registration problems in one swell foop, and now appears to be eminently hackable.

The key Cycolor secret lies in the materials used. Figure one shows details. Picture three different egg-like packages known as *cyliths*. Each cylith is around one-third of a mil (0.0003 inch) in diameter. Zillions of them are uniformly spread out one cylith deep over a polyester carrier, similar to a piece of photo film.

Each cylith starts out with a soft outer shell. The first cylith type is full of a liquid cyan (process blue) *leuco* dye. The second cylith type is full of magenta (reddish-purple) dye. The third cylith type is full of yellow dye.

The cyliths shells are sensitive to different color light. On exposure, the cyliths will *harden*. For instance, red light will harden the cyan cyliths but leave the magenta and yellow ones soft. White light will harden all of the cyliths, while black (no light at all) will leave all the cyliths soft.

To create a color print or slide, an image is projected onto the developer sheet containing all the cyliths. After exposure, your developer sheet will consist of a mixture of hard and soft cyliths. You now have a *latent image* on your sheet that is somewhat similar to a color negative.

The developer sheet is then placed in pressure contact with a suitable paper, slide, or transparency material. The pressure breaks all of those soft cyliths, releasing their internal dyes. The hard cyliths remain intact and do not release their dye.

For instance, if you've got hard cyan cyliths and soft magenta and yellow cyliths, then the magenta and yellow dyes will get released and will mix to form a red image. For a blue image, those yellow cyliths harden, leaving the magenta and cyan cyliths soft. Squashing the soft cyliths mixes a magenta and cyan to produce a deep blue. And so on.

One more time. Bunches of cylith capsules are on the polyester carrier.

Some of the capsules get selectively hardened when exposed to light. A pressure roller then squashes the soft capsules, releasing their dye onto a suitable final paper, plastic, or slide material. Like stomping on balloons. A brief heating completes the imaging process. Neat stuff.

A free and interesting brochure on Cycolor is obtainable through *Mead Imaging*, while the leading companies offering Cycolor machines include *Brother*, *Noritsu*, *Pic-Mount*, and the folks at *Seiko-Mead*.

Probably the best way to start off hacking this stuff is to get free demos of the various machines and then rip off small quantities of the supplies for your own testing and use.

I can think of dozens of specialized hacker uses for this new technology.

What can you come up with?

Low Noise Amplifiers

The best of new integrated circuit amplifiers now offer noise levels that are much lower than a circuit built up from discrete components, and are significantly lower than what vacuum tubes used to be able to accomplish eons ago.

Four of the leaders in the field of ultra low noise chips include *Linear Technology*, *Precision Monolithics*, *Burr-Brown*, and *Analog Devices*.

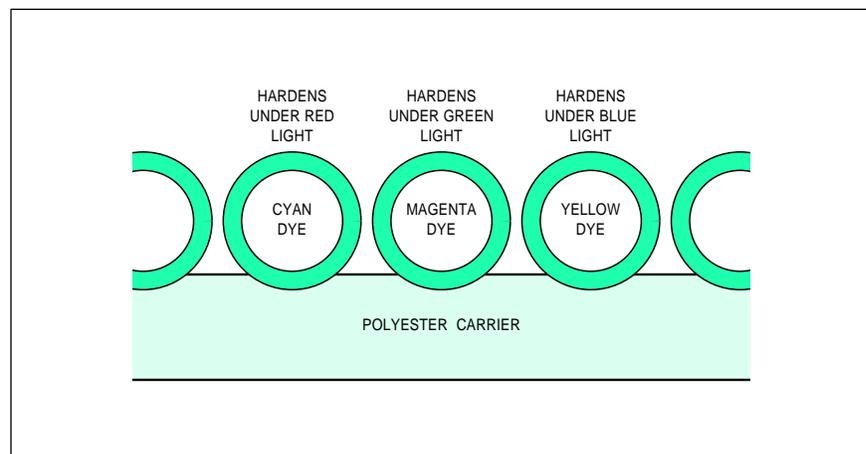


Fig. 1 – THE CYCOLOR PROCESS uses tiny cylith microspheres. Each of these cyliths is initially soft, but hardens under exposure to certain light wavelengths. Crushing the soft cyliths releases a final image dye.

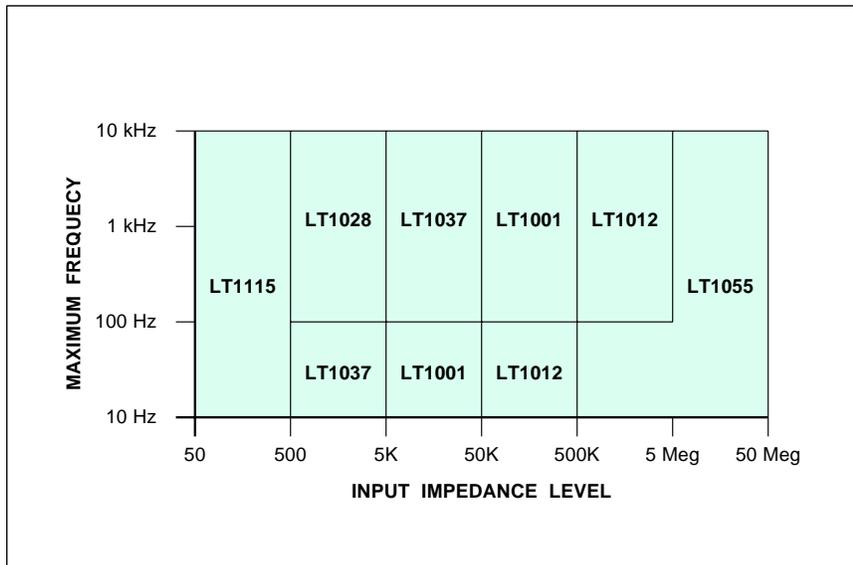


Fig. 2 – ANY LOW NOISE AMPLIFIER must get specified over a certain input impedance level and a certain frequency range. Here are Linear Technology’s selections for the "best" low noise op-amps. Note that a misapplied "low-noise" amplifier can actually be noisier than a regular one.

While all of these sources have lots of free and excellent technical info available, I am most impressed with the *Linear Technology* offerings at the present time.

But, before we really get into this, let us shatter several hacker myths involving low noise amplification.

Firstoff, in no way will a low noise amplifier by itself *reduce* the noise

from an already noisy source. All a low noise amplifier can do is limit the amount of extra noise *added* by its own amplification process.

Second, in the overwhelming majority of hacker circuits, most noise problems are caused by an improper circuit layout, sloppy decoupling, by instabilities, poor shielding, and by undesired ground currents. Switching

from an ordinary ic to a low noise amplifier in such instances will not in any significant manner reduce your apparent output noise. It could even make things much worse.

Third, the wider the bandwidth, the more noise you are going to have. The wideband circuits are all inherently noisier than narrow band ones. All other things being equal, noise will increase as the *square root* of your bandwidth. Most often, if you quadruple your bandwidth, you double the noise involved.

Fourth, integrated circuit noise does tend to increase very dramatically at extremely low frequencies. If a precision dc response is not needed, you should be better off capacitively coupling an ac or audio amplifier.

Fifth and finally, circuit noise is a very strong function of frequency and source impedance. There is no such thing as a universal "low noise" amplifier. In fact, a "low noise" amp run in the wrong frequency range or at the wrong input impedance will actually generate *more* noise than might a plain old op-amp.

Thus, if you want low noise, it is super important that you have all the data sheets and applications literature on hand for the device you want to use, plus a thorough understanding of the options available in other chips from other sources.

There are two types of noise that the first stage of an integrated amplifier can generate. These are *voltage noise* and *current noise*. It turns out that current noise is *directly* proportional to the square root of the first stage collector current, while voltage noise is *inversely* proportional to the square root of the collector current.

Iffen the right one don't git ya, the left one will.

Voltage noise tends to be constant with frequency and more important at *low* impedance levels, while current noise tends to increase sharply below a *noise corner* (or "1/f") frequency in the low audio range. Current noise is more important at *higher* input impedance levels.

Voltage noise is usually measured in *nanovolts per square root of bandwidth*, with any value under 1.0 being fairly decent.

Current noise gets measured in units of *picoamperes per square root of*

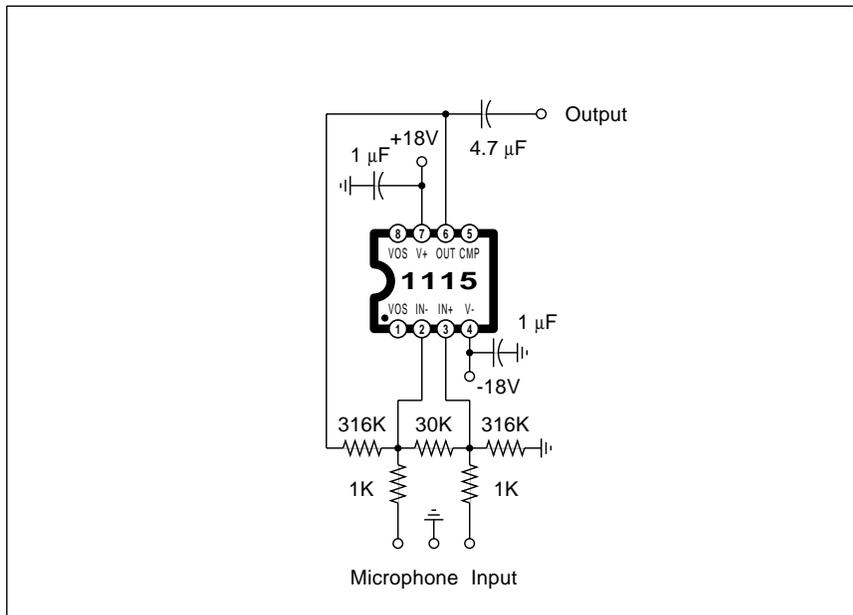


Fig. 3 – AN ULTRA-LOW NOISE BALANCED PREAMP circuit that uses the Linear Technology LT1115. Noise and distortion is under 0.028 percent.

bandwidth, again with anything under 1.0 being desirable.

Figure two does show us several possible selections for *Linear Technology* amplifiers that will give you the "best" noise performance for a given impedance level or frequency range. Of the previous generation devices, that *Precision Monolithics* OP-37 is considered the "parent" of these newer low noise devices in the same way that the original 741 started the whole op-amp universe.

Let's look at a typical device. The *Linear Technology* LT1115 is an ultra low noise and low distortion audio op amp. It works best when ac coupled at higher gains and over an optimum input source impedance of 30 to 300 Ohms. Figure three does show you a simple microphone preamplifier that receives balanced inputs (for hum cancellation) and provides a single-ended output with a gain of 300.

The total of combined noise and harmonic distortion is under 0.028 percent over a 20 Hertz to 20 Kilohertz bandwidth.

Should you truly and genuinely need the lowest voltage noise possibly get and already have total and absolute control over all the usual ground, hum, stability, and stray noise sources that usually swamp hacker circuit first stage noise figures, there is one sneaky trick you can pull.

Simply arrange several low noise amplifiers in parallel and sum all of their outputs into a second-stage low noise amplifier. The gain goes up with the number of amplifiers, while the noise only goes up as the square root of the number of amplifiers in use.

Five parallel amplifiers seems a practical limit, which, in theory can reduce your first stage noise by a factor of slightly over two. In the real world, this only works for input impedances less than ten ohms. Worse yet, circuit strays are likely to eat you alive if you attempt this. More details on the LT1028 data sheet.

Unusual Mechanical Goodies

There has been plenty of unusual non-electronic stuff piling up here lately, much of it with great hacker potential. Time for a rundown.

First and foremost, if you really want to get a handle on things, pick up your free sample kit from *GripWorks*.

A new material known as *Trovicel* looks like a really good board product for use on everything hacker from cases through prototype models and displays. Trovicel is a rigid foam-center plastic sheet that comes in lots of attractive colors and in several thicknesses. It is lightweight, tough, paintable, outdoor rated, printable, pretty, and self-extinguishing. You work it with pretty near any hand or power tool, although hacksawing and power shearing are not recommended. You can bond it with ordinary PVC cement, and even grind or weld it. Free samples are available.

Should you need any curved plywood in tubes, quarter-round, half-round, or with a radiused end, try out some of the *Deco Shapes* product from *Laminates Incorporated*.

There seems to be a lot of interest lately in *machinable waxes*. Besides being obviously ideal for CAD/CAM training and program debugging, the material is well suited for one-of-a-kind mockups, proof-of-concept models, and for "does-it-fit?" product verification.

With a machinable wax, your tools stay sharp, the chips are safe, and you can easily recycle your final material simply by remelting it.

The product is available from two to

eight inches thick; in cylinders up to nine inches in diameter; and in bulk. You could easily recast their wax into any shape you want to. It melts at 310 degrees Fahrenheit.

One good source for machinable waxes is *Freeman Supply*. Prices start at \$4 per pound.

The *American Safety Razor* folks are obviously one sharp outfit. Their catalog lists zillions of different low cost blades, including ripple ones for cutting potato chips and big mutha ones nearly *eighteen inches* long! The variety here is amazing.

One obvious project around here is a \$5 cutter for laser printed business cards. I'm wondering if you couldn't use their blades for a clamping paper cutter as well. A proper support, of course, would be essential.

In what just might be the most obscure free trade journal in the entire world, *Power and Bulk Solids* covers such things as bin level detectors and similar goodies. Amazingly, several hacker helpline callers per week are asking for this sort of stuff, especially for agricultural electronics.

A new product called *Scotch 9703 Conductive Adhesive Transfer Tape* from 3-M has a very unusual property. It can conduct electricity *through its thickness* but not along its length.

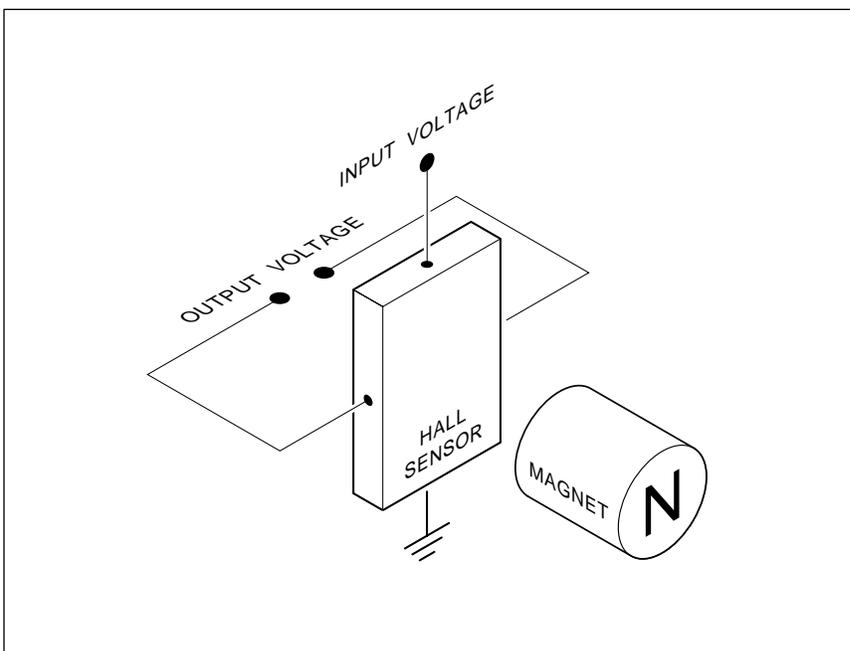


Fig. 4 – THE HALL EFFECT in a semiconductor will produce a transverse output voltage that is proportional to the strength and direction of a magnetic field. Analog or digital Hall devices are available.

From face to face, the resistance is under 0.1 Ohms. Yet, along its length, it insulates to the point of allowing 500 volts across a ten mil gap!

Embedded silver-plated particles apparently are the secret. Adhesion values are in the 50 ounces per inch range for most substrates. Free test samples are available.

Finally, short shape metal alloy wire samples are available free from *Beta Phase*. These magic wires can be bent into any shape at all and will stay that way until heated to hot coffee temperatures. Then they'll rapidly spring back to their original size and shape. You can repeat their shape-and-restore process zillions of times. Applications include everything from high density zero-insertion-force connectors to dentistry.

Tellyawhat. For this month's contest, just dream up an off-the-wall use for any of these unique new materials. They'll be the usual dozen or so *Incredible Secret Money Machine* book prizes, along with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.

As usual, send all your written entries directly to me at *Synergetics*, rather than over to **Radio-Electronics** editorial offices.

Hall Effect Devices

There are lots of different ways of sensing magnetic fields, ranging from a compass on up. In past issues and in the *Hardware Hacker* reprints, we've looked at the *flux gate magnetometer*, that appears to be far and away the best method for sensing and measuring the Earth's magnetic field.

Another magnetic field sensor is called a *Hall Effect Device*. While not nearly sensitive enough for accurate electronic compass uses, a wide range of Hall devices are available for use in position and speed sensing devices that can interact with nearby magnetic materials.

Our resource sidebar for this month reveals to you a few of the leading sources of useful Hall Effect products and information.

Figure four shows you how the Hall Effect works. A thin film of selected semiconducting material has a current applied to it from a top edge terminal to a bottom edge terminal. Two additional contacts are placed midway along the sides of the film. The Hall voltage will develop across these terminals.

In the absence of any magnetic field, the current will end up uniform

across the film, and there will be no Hall output voltage.

Now, should a magnetic field be applied into the film, the current will shift towards one edge or the other, and a Hall voltage will be generated whose strength is proportional to the magnetic field and whose polarity depends on the polarity of the applied magnetic field.

This Hall action is related to the magnetic deflection in a television picture tube and follows the "right hand rule" where the resultant force of a magnetic field causes an electron beam current to move sideways.

The Hall voltage is usually rather low, and is typically in the tens of millivolts. In most Hall applications, fairly strong magnets must be placed quite close for reliable operation.

In general, there are two types of Hall Effect sensors, *linear* and *digital*. Linear sensors are used whenever you wish to measure the actual strength of a magnetic field. A *Gaussmeter* is one instrument that can use Hall Effect devices to measure medium-strength magnetic fields. *F.W. Bell* is a major source for the precision linear Hall devices and instruments.

Digital sensors are used whenever the presence or absence of a magnetic field is intended to produce a "yes-no" output. Figure five shows you one typical digital Hall Effect sensor, the Sprague UGN-3013. Which is a three terminal device about the size and shape of a small signal transistor. The price is under a dollar.

A supply voltage is applied. While this can range from 4.5 to 25 volts, the usual +5 is typical. There is an open collector output that is *off* in absence of a magnetic field. Note that you have to provide an external pullup resistor to get any output. Typical supply current is three milliamperes, plus the "on" current through the load resistor.

This chip is guaranteed to turn on with a magnetic field of 500 Gauss, or roughly 500 times the strength of the Earth's magnetic field. It's also guaranteed to turn off with a magnetic field of less than 30 Gauss. To prevent chattering or noise, a snap-action hysteresis of 75 Gauss or so is usually provided via an input Schmitt trigger.

A cheap *Alnico* magnet a third of an inch in diameter and a quarter inch thick will activate your chip from a

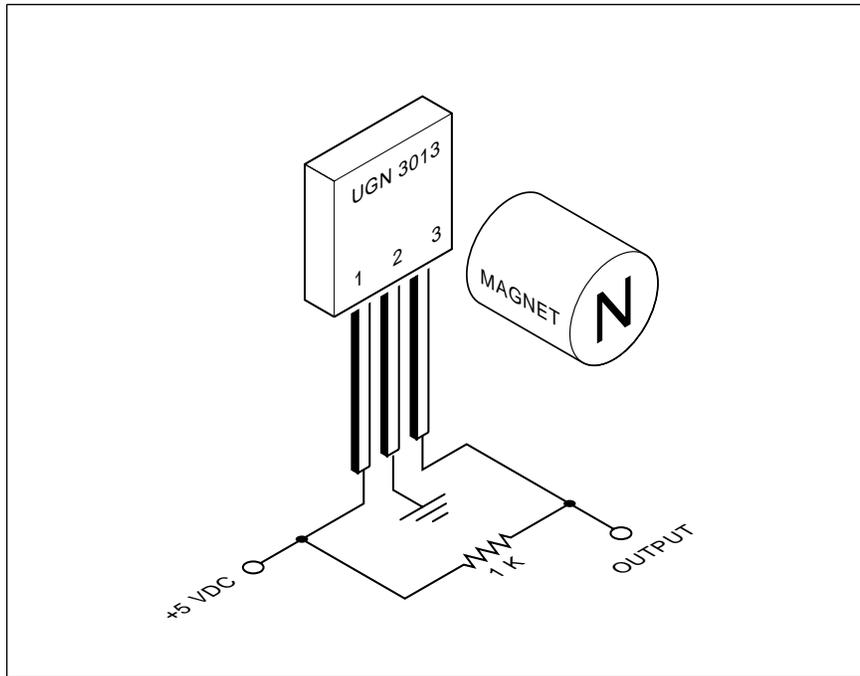


Fig. 5 – THE SPRAGUE UGN3013 is a low cost Hall Effect sensor having a snap action digital output. The open collector output remains high in the absence of a magnetic field and goes low when a field is present.

distance of 0.15 inches. Sensitivity drops off dramatically with distance. On the other hand, *flux concentrating* pole pieces can be added for extended range. As can stronger magnets.

Other devices are available with different sensitivity. Some are *bipolar* in which you purposely *reverse* the applied field, rather than dropping it to zero. This can give you a more reliable sensing as alternate poles of a magnet go flipping on by.

Two excellent and sometimes free books on the Hall Effect include the *Hall Effect Sensors* data book SN-500 from *Sprague*, and the *Hall Effect Transducers* applications book from *Micro Switch*. The latter shows a \$10 optional list price.

There are bunches of hacker uses for Hall Effect devices, since they can sense though a modest non-contacting distance in a dirty environment. Obvious digital uses now include high reliability keyboards, automotive ignition contacts, shaft angle encoders, position detectors, for model railroad controls, speed sensing, brushless dc motor commutation, and tilt switches.

Linear applications include current sensing, circuit breakers, and direct magnetic field measurements.

Hall devices also show up in all the usual surplus catalogs, and in many of the ads that you'll find right here in **Radio-Electronics**.

New Tech Literature

Certainly the fanciest data books in the industry are in the free series available from *Omega Engineering*. These thick hardback volumes now include their *Temperature; Flow and Level; Data Acquisition; Conductivity and PH; Pressure, Strain, and Force*; and *Electrical Heaters* handbooks. They all include useful engineering info. And, all of them are available free upon a professional-sounding request. Unfortunately, the Omega prices are extremely high. Then again, they would have to be to pay for the aggressive distribution of all of their exotic catalogs.

Other data books this month include the new *Precision Analog and Power Control IC Handbook* from *Teledyne*, and a new *Linear Integrated Circuits* databook from *Raytheon*. Looking at short forms, *Sharp* has a pair of them out, one titled *RF Components for*

HALL EFFECT DEVICES AND RESOURCES

F. W. Bell

6120 Hanging Moss Road
Orlando, FL 32807
(407) 678-6900

M & C Magazine

2994 West Liberty Avenue
Pittsburgh, PA 15216
(412) 343-9666

Micro Switch

11 West Spring Street
Freeport, IL 61032
(815) 235-6600

Sensors Magazine

1244 Reamwood Avenue
Sunnyvale, CA 94089
(408) 744-1500

Siemens

19000 Homestead Road
Cupertino, CA 95014
(408) 257-7910

Sprague

70 Pembroke Road
Concord, NH 03301
(603) 224-1961

Texas Instruments

PO Box 809066
Dallas, TX 75380
(800) 232-3200

Wabash Magnetics

1375 Swan Street
Huntington, IN 46750
(219) 356-8300

CATV Systems, and the other *RF Components for Satellite Receivers*.

And two free new surplus flyers—*MWK Industries* for lasers and optics, plus *Silicon Valley Surplus* for great robotics prices.

What appears to be a stupendous breakthrough is described in *A light source smaller than the optical wavelength*, beginning on page 59 of the January 5, 1990 issue of *Science*. This one is downright scary in its potential.

Free samples this month include a MC14507 single supply RS-232 driver from *Motorola*, a Johnny come lately imitation of those *Maxim* chips that pioneered this field. Also, a bunch of freebie chips from *Texas Instruments*. These include their TL499A battery backup DC-DC converter, a TL1451A pulse width modulator chip, and their SN75C188 line driver circuit.

TI also has free samples of all their new OTP (one time programmable) EPROMs. These work like a "real" EPROM, except they are in a cheaper plastic case and can only get programmed one time. You use them for repeat copies of known good code.

From *NEC*, the new *Digital Signal Processor and Speech Processor* data book. And from *Silicon Systems*, a *Microperipheral Products Data Book* that covers chips used in floppy disks, hard disks, and cassette tapes.

Free software this month includes a *Generic Array Logic Demo* through *SGS-Thomson* and a *CUPD Demo Disk* From *Logical Devices*. Included here is a *My First PAL Design* booklet.

Tektronix has a new and free *Scope Evaluation Kit* available that includes a test circuit board which purposely generates overshoots and hard to see glitches. They also have several free oscilloscope videotapes available.

Surprisingly cheap (\$3.95) analog hygrometer humidity instruments are available from *Klockit*.

Turning to other mechanical stuff, *Stock Drive Products* has a new data book and master catalog available on such things as gears, belts, couplings, robotics breadboards and such.

To improve the appearance of your prototypes, the *DonJer* folks have low cost "instant suede" applied via liquid glop and a cabbage duster. 28 colors are available, as is a \$52 professional starter kit. A nice effect.

Yet another reminder here that the *Midnight Engineering* is a great new hacker magazine aimed at all you small-scale hardware and software productions. Free samples are available by special arrangement.

Turning to my own products, for the fundamentals of digital integrated circuits, check into both my classic million-selling *TTL* and *CMOS Cookbooks*. I do have some autographed copies on hand here for you.

I also have a new and free mailer for you which includes dozens of insider hardware hacking secret sources. Do write or call for a copy.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box in the appendix. ♦

Don Lancaster's Hardware Hacker

June, 1990

Electronic Levels
Low Cost Memory
New Form of Matter
Cases and Enclosures
LaserWriter Tech Info

Someone at long last has done something right for a change. Hacker friendly too. A giant *Yea Team!* and a sixpack of *attaboys* to all of the folks at *Dallas Semiconductor*, a manufacturer of innovative new integrated circuits.

Dallas has set up a free 24 hour direct order line with no hassles and no minimums. If you want one or two of their chips at 3:42 in the morning, just whip out your VISA card and give them a call. For next day delivery.

What's really sad is that virtually all of those other "good guy" innovative chip manufacturers invariably use by far the most Neanderthal and the most hacker vicious of the old-line distribution channels.

So here and now, I issue an outright challenge to all the rest of the "good guys" - *Maxim*, *Sprague*, *Linear Technology*, *Samsung*, *Mitsubishi* (who has far and away the most mesmerizingly awful reps and distributors in the industry, bar none), *Signetics*, *Reticon*, *SGS*, *Statek*, *Telton*, *Rohm*, *Intersil*, *Sony*, *Siemens*, *Philips*, et. al.

For your own good, please, please, find out why *Dallas* is laughing all the way to the bank. And please set up your own direct order lines that do not go out of their way to kick sand in the collective faces of your most promising future customers. Your present distributors are your worst enemy.

As usual, please observe that all of our referenced sources do appear in either the upcoming *Cases and Enclosures* resource sidebar or in the *Names and Numbers* box. Please do check out these sidebars before using our free help line. And please do make all your product and your literature requests to anyone listed in either sidebar specific, rather than general.

We return you now to our column already in progress...

LaserWriter Technical Information

It appears that *Apple Computer* has gone far out of their way to prevent you from ever getting any useful parts or technical service information on

their *LaserWriter* printers. Outside of the limited "white book" *LaserWriter Reference* on all of those connections and the commands (in stock here at *Synergetics*), virtually nothing at all is available from them on their printers. Such stupidity ends up monumentally short-sighted.

Fortunately, *Hewlett-Packard* is as hacker-friendly as *Apple* is hacker-vicious. The *Canon CX* and *SX* engines used by both companies in their printers are nearly identical. Over 95 percent of the mechanical parts are fully interchangeable. And HP, Like *Dallas Semiconductor* above, also has a free VISA order line with overnight express delivery.

HP has a pair of outstanding service and repair manuals that are directly applicable to all the *Apple* printers. Their manual #33440-90920 is for the older *CX* engine as used on the *LaserWriter* and *LaserWriter Plus*. Their manual #33440-90904 is for the newer *SX* engine that is used on the *LaserWriter NT* and *LaserWriter NTX*.

Unfortunately, HP sells only the replacement modules, and rarely goes

down to the individual component parts level. Thus, you can get a fuser assembly from them, but not a fuser roller. One source I've found useful for any and all *LaserWriter* parts on any level is *Don Thompson*, who also stocks detailed repair literature, low cost rebuilds, toner supplies, and the handy and useful repair tools. One additional source for a *LaserWriter* schematic is *Bomarc Services*.

As we have seen before, you can easily refill your own *SX* or *CX* toner cartridges in two minutes for \$7.50. The job is much simpler than properly packaging your cartridge for shipping to a commercial refilling service.

Besides *Don Thompson*, another major source of refilling supplies that I personally use is *Arlin Shepard* of *Lazer Products*. Arlin also now offers "infinite life" recoated *SX* drums. One I'm now using is on its 14th refill.

From what I have been able to determine, much of the rest of the toner refilling industry is an outright zoo. We have people selling you shoe polish and calling it drum recoating, others gold plating things that do not

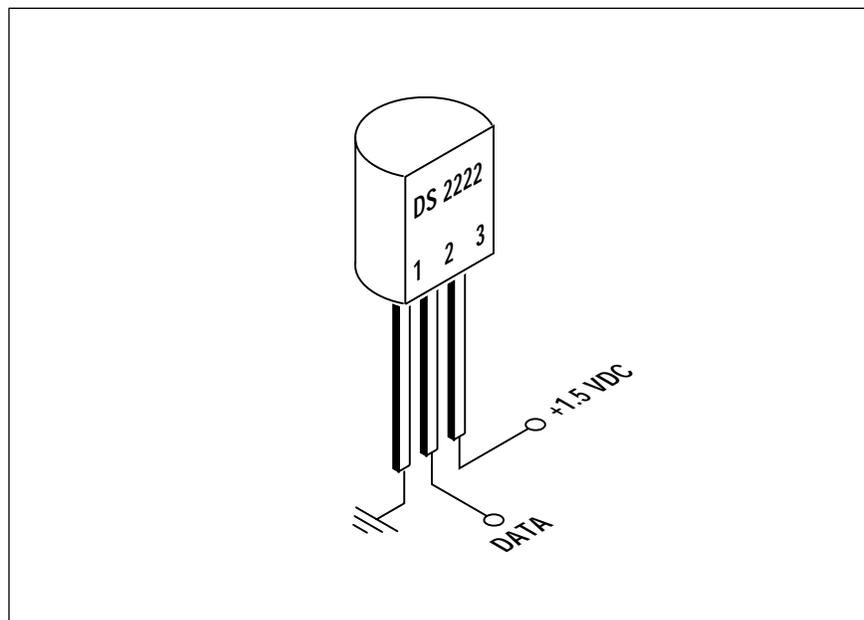


Fig. 1 - THE ECONORAM IS A MICROPOWER memory of 256 bits. These can cost less than a quarter each in quantity. Amazingly, all addressing, data transfers, and all read/write control are done through one very busy pin!

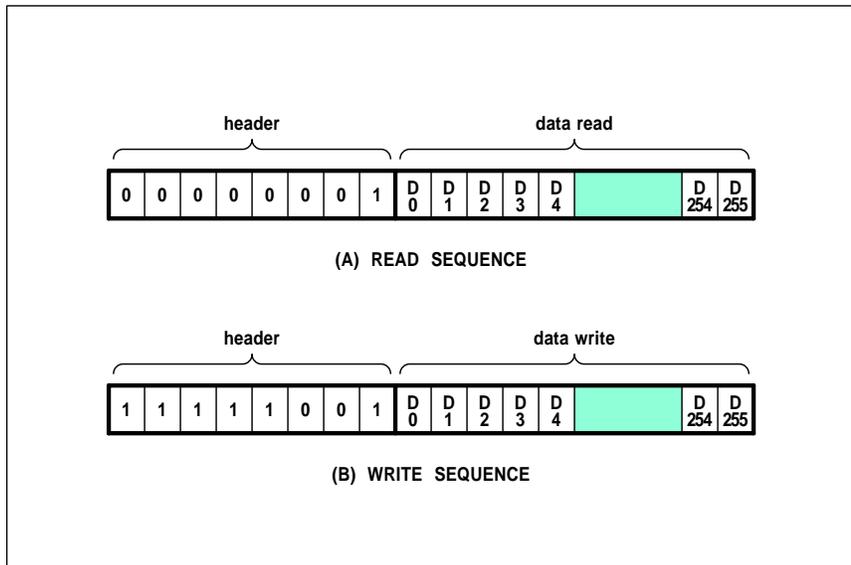


Fig. 2 – THE ECONORAM GETS INTERROGATED by use of 264 sequential timing pulses. Once started, the sequence must get completed in its entirety. See the DS2222 data sheet for additional details.

need gold plated, and yet others who are making useless "gapping" adjustments that try and compensate for the shoddy quality of their toner.

For a good glimpse into the entire toner refilling industry, check out the highly interesting and informative *Recharger* trade journal.

Full details on the toner cartridge reloading appear in previous columns and in my *Hardware Hacker II* book-on-demand published reprints.

Low Cost Memory

In case you have not met them before, *Dallas Semiconductor* has a mind-boggling array of cheap and innovative new circuits that cry out for hacker use. They are very heavy into clocks, non-volatile memory, supervisory watchdogs, FCC legal "plug-and-go" telephone modules, and the short-range RF remote controls.

One typical example is their DS2222 *EconoRAM*, shown you in figure one. This is a 256 bit nanopower memory that is easily made non-volatile with a tiny backup battery. It is intended for intelligent credit cards, public transit tickets, security access control, trade show customer identification, long term data acquisition, and user ID keys. Or anywhere else you want to cheaply store a few bits of information that has to be nanopower, compact, and highly portable.

The cost is under a quarter in large enough quantities. Supply voltage is between 1.2 and 4 volts dc. Standby operating current is a mere 100 nanoamperes. Less than one milliampere is needed for a read or write operation. A typical small coin cell is good for 100 million transactions over several years of operation.

What boggles the mind is that there are only *three* pins on the DS-2222. Power, ground, and a single pin that, believe it or not, performs all of the addressing, data transfer, and control of reading and writing.

You just about have to use a host microprocessor or personal computer to read or write to this chip, since the process is so involved. Here's how it usually works:

To read or write any one bit, all bits must get read or written. Figure two shows details. Your host controller provides a high output and then issues a string of 264 pulses. The timing can be any interval longer than 60 microseconds per pulse.

Each pulse event begins when the output drops from supply to ground. When writing, a logic one must last between 1 and 15 microseconds. A logic zero must last at least 60 microseconds. And so, the *length* of your write pulse determines whether you enter a one or a zero.

When reading, you have your host

hold the output low for between 1 and 15 microseconds. The EconoRAM should respond by remaining low for another 15 microseconds if a zero is stored, and by immediately going high if a one is stored. Thus, to read, bring the output low for 15 microseconds. Wait 5 microseconds. Then sense the one or zero.

The first 8 bits in your sequence are called the *command word*. The first five are all ones to write, or all zeros to read. This is followed by a pair of zero bits which allow a later memory expansion. The eighth header bit is always a one.

The remaining 256 bits are your data, arranged in a sequentially addressed order. Which is much like a shift register would work. To change a single bit, you first read all of the bits, store them in host memory, and then rewrite all of the bits, changing what you want on the fly.

Obviously, this RAM is best suited for long term storage applications only occasionally read from or written to. A 5K pullup resistor is recommended when writing or reading. The output pin is TTL compatible.

Now for the tricky part. To first initialize your EconoRAM, you send it 264 write zero states. This automatically resets the internal address counter. After that you send a new sequence to do whatever reading or writing you care to. Remember that you must go completely through a sequence each and every time or the EconoRAM will get confused.

Four EconoRAM's are easily used together for a full 1K that should be enough for a complete name, address, and account number. All you do is change the address bits in your command string through 00, 01, 10, or 11. As many as 32 bits could also get permanently factory written in for a positive and genuinely non-volatile message header.

Let me know what new hacker uses you might come up with using this innovative new approach to small memory needs.

Cases and Enclosures

For this month's resource sidebar, I thought we'd round up some low cost products and materials that let you design your own electronic cases and enclosures.

Obviously, if you just need a plain old box, your local *Radio Shack* has several bargain priced ones in stock, as does *Mouser Electronics*, as well as nearly all of our other fine **Radio-Electronics** surplus advertisers. The trick is to find something beyond a plain-jane box that looks sharp, makes a statement you can relate to, and isn't outrageously expensive.

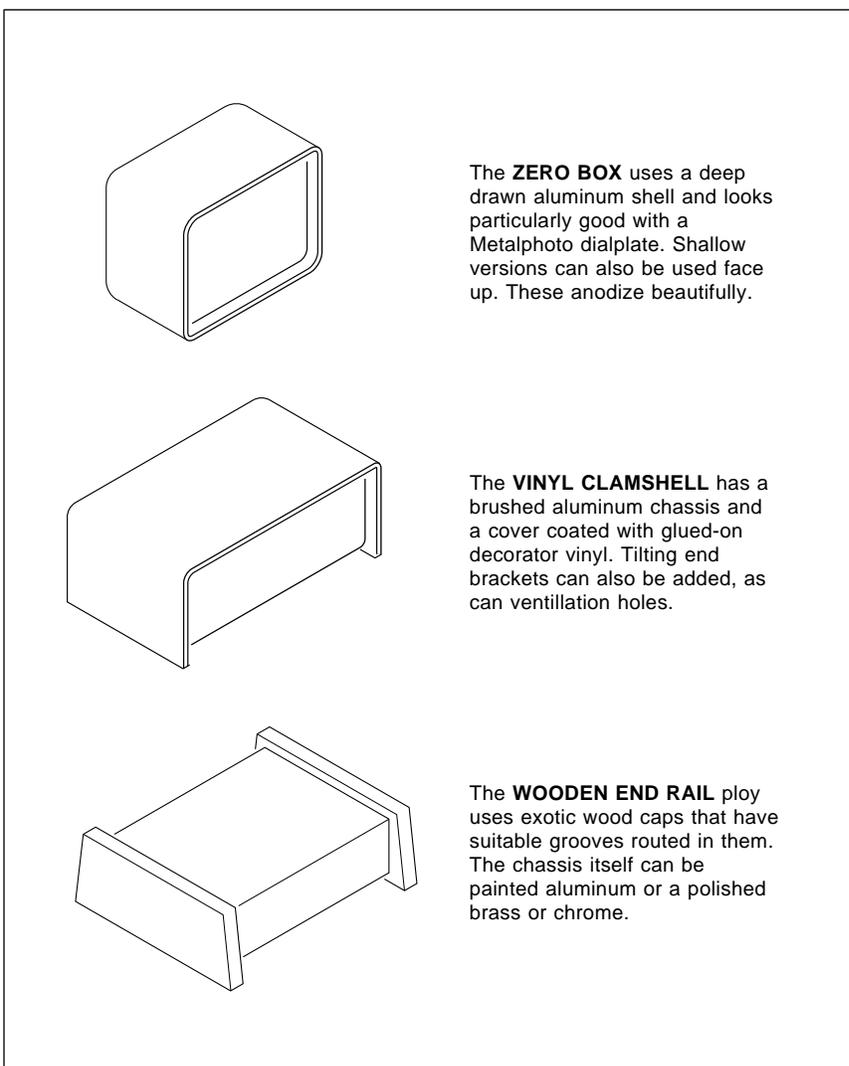
Let's briefly run down the major case and enclosure manufacturers: *Bud*, of course, who is pricey, very old line and uninspired; *Vero* having a foreign look about them; *Hammond* with a good selection of ABS mini-cases; *Polycase* who feature the wall mounted and plug-in stuff; *PacTec* with an incredible variety of sloping small consoles; *Keystone* for built-in battery compartments and standoffs; *Serco* for some fancier, highly styled boxes; and *Vector* who are both low cost and look it.

Want to wrap your own instead? Figure three shows you three of my own favorite home-brew packages from way back when. While most of the *Zero Manufacturing* cases are ludicrously expensive, they also do offer a line of plain old deep-drawn aluminum boxes with rounded corners in zillions of sizes that are reasonably priced. These anodize beautifully, and many models have lids which exactly provide an outside or an inside fit. And the photographic dialplate materials from either *Metalphoto* or *Fotofoil* can integrate beautifully with these cases.

For dozens of examples of these, check into the back issues of **Popular Electronics** and **Radio-Electronics** in the 1965-1975 time frame.

Vinyl clad materials are used by all the big folks. Getting them in small quantities can be a real hassle. Instead, you simply go on down to your local *Yellow Front* or an equivalent yuppy pseudo-surplus store, buy some fake Naugahyde by the yard, and glue it onto plain old aluminum or steel. The "clamshell" design of figure 2-B is easy to do. You can simply sand the bottom half to get a satin finish, and glue vinyl onto the upper half to get a professional final result.

The *wooden rail* ploy of figure 2-C is both easy to hack and looks great. Just get yourself some exotic wood from *EDLCO* or *Constantine* (Coco-



The **ZERO BOX** uses a deep drawn aluminum shell and looks particularly good with a Metalphoto dialplate. Shallow versions can also be used face up. These anodize beautifully.

The **VINYL CLAMSHELL** has a brushed aluminum chassis and a cover coated with glued-on decorator vinyl. Tilting end brackets can also be added, as can ventilation holes.

The **WOODEN END RAIL** ploy uses exotic wood caps that have suitable grooves routed in them. The chassis itself can be painted aluminum or a polished brass or chrome.

Fig. 3 – HOMEBREW CASES FROM the "golden age" of hardware hacking. All of these are easily built, yet can produce outstanding professional results.

bolo or Wenge are fine choices), mill some slots in it with a hobby motor tool, slide in a bent metal frame, and you are home free.

I've found a local blacksmith or sheet metal shop to be real handy at times, so you'll want to find a good one of these on your own. Better yet, see if you can't find a horse trailer or hitch works. They have the machinery to properly cut and bend the heavier stuff without costing an arm and a leg. And there's usually enough scrap on the floor under the shear.

Four interesting package support outfits are the *Fomeboards* people which do stock all sorts of beautiful prototyping sheet materials; *Coburn* who is heavy into unusual finishes

such as prismatics, glow-in-the-darks, diffraction gratings, foils, etc; instant dust-on flock materials from *DonJer*, and the *Ultra-Suede* from *Red Spot*, a textured urethane finish having a soft fuzzy suede or smooth leather touch.

All the enclosure and packaging people advertise in most of the free electronic trade journals. *Electronic Component News* seems about the best for cases and such. Two other trade journals with useful fit and finish ideas in them do include both *Electronic Packaging* and *Appliance*.

If you have any favorite homebrew packaging ideas of your own, please send them in to me so we can share them with the others. There are all sorts of possibilities here.

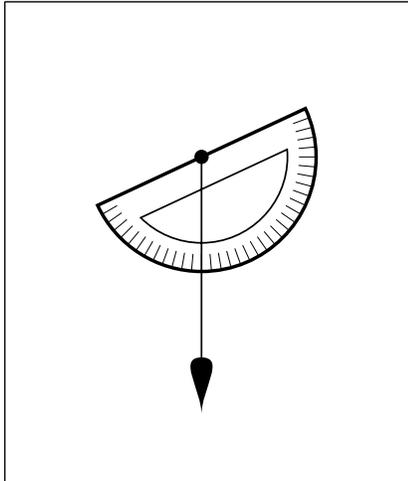


Fig. 4 – A SIMPLE INCLINOMETER can be created by using nothing but a plumb bob and a protractor. You sight along the base of the protractor base and then read the angle.

Electronic Inclinometers

The folks at *Wedge Innovations* are now retailing intelligent electronic levels which display your choice of degrees, pitch, slope percent, level & plumb, autocalibration, and even a simulated bubble. The suggested list price is under \$80. Related electronic protractors are being offered by *Lucas Sensing Systems*. I just thought we might take a quick look at some of the principles of electronic level sensing. You can easily build your own level sensor for under \$4.

In general, there are two popular ways of telling which way is up. One quite expensive method is the *vertical gyro*. This is simply a gyroscope that is spun up while level and stays that way when the world around it moves. Two surplus sources of vertical gyros include *Fair Radio Sales* and the folks at *C&H Sales*.

A much simpler method is the *inclinometer*. As figure four shows us, an inclinometer can be as simple as a plumb bob and a protractor. Your gravity sensing plumb bob usually points straight down. As the protractor is rotated, its slope angle can be read.

There have been several older attempts at getting an electrical output off an inclinometer. Obviously, you can simply wipe a potentiometer, but stiction, wear, and hysteresis can end up as problems. Other early schemes

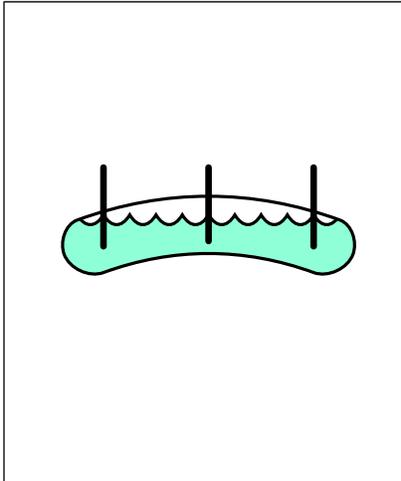


Fig. 5 – AN ELECTROLYTIC LEVEL is one older electronic inclinometer. As it tilts, the bridge resistance between the sensing pins will change. Bromine is one possible liquid.

used mercury, a hazardous element that's both poisonous and rather low in impedance.

Figure five shows you another early attempt at an electronic inclinometer. This one is known as an *electrolytic sensor*. You place three probes in a conductive liquid in a sausage-shaped enclosure. As the sensor tilts from level, the deeper probe's resistance drops, while the shallow one will increase. A simple op-amp bridge circuit can convert this differential resistance into an output voltage.

One obvious choice for a liquid is bromine, one of those few elements which remain liquid at normal temperatures. Two older sources of the electrolytic level detectors are *Hamlin* and *Spectron*. These devices are both fragile and expensive.

Optical shaft encoders could be used, but an absolute encoder would have to have at least twelve bits of resolution for decent accuracy.

Most of the bets these days, though, are on the *capacitance inclinometer* shown you in figure six. This one is simple, cheap, low power, and clean.

Picture an insulated enclosure the size and shape of a Magician's fake silver dollar. The rear of the enclosure is a grounded metal plate. The front consists of a pair of butterfly shaped capacitor plates. The case gets filled exactly halfway with a magic liquid that is an inert insulator, has a high

dielectric constant, a medium viscosity, is non-wetting, non-corrosive, and has a very high vapor pressure. Although propylene is one possible choice, there are lots of silicone oils that should serve as well.

After filling, your case is sealed. When level, each of those butterfly plates will be immersed just as deep in the dielectric liquid. As the sensor tilts, one plate goes deeper and the other will become shallower, thus changing the capacitance. The higher the dielectric constant of the liquid compared to air, the more profound the capacitance change.

To sense, you let each wing of the butterfly set your pulse width of a monostable built out of a pair of 555 timers or one single 556. You then measure the time difference between the two to determine the angle. Obviously, a low-end microcontroller could greatly simplify your digital display. Far and away my favorite here would be a *Mitsubishi M50734* or one of its single-chip alternatives.

To get fancier, place a pair of the sensors back-to-back and sharing a common ground. This gives you two big advantages. First, your sensed capacitance change is now doubled, which should give you more accuracy. Better yet, your *cross axis sensitivity* should drop dramatically. This will happen because an unwanted forward or reverse tilt increases the depth on one side and decreases it on the other.

The shape of the plates determines the linearity of the capacitance versus the slope angle. Sometimes, you may like to purposely change the plate shape to get a non-linear response. One use might be to automatically calculate compound miter cut depth on a table saw.

It seems to me you could easily make up a capacitance sensor using nothing but a pair of printed circuit boards, a spacer and a large O-ring. The bottom board would form the ground plane. The spacer would have a hole in it somewhat larger than the O-ring and would act as a compression stop, setting a fixed width. And the top one would have the butterfly pair on it.

Er, on second thought, why don't you tell me? For this month's contest, either (A) show to me an eminently hackable design for the capacitance inclinometer, or (B) dream us a new

use for an electronic angle measuring device. There will be all the usual *Incredible Secret Money Machine* book prizes, with an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best entry of all.

As always, send all your written entries directly to me at *Synergetics*, and not to **Radio-Electronics** editorial.

New Tech Literature

A brand new form of matter known as an *aerogel* got written up in the February 16th, 1990 issue of *Science*, page 807. Aerogels are rigid inorganic solids that have roughly the density of air and look like so much solidified smoke. They transmit light but block heat, electricity, and sound.

You can make aerogels from mine tailings dumps. Important early uses are expected to be brand new types of superinsulation and for the live capture of meteors. Neat stuff.

The new Data books for this month include the *Data Communications Handbook* from *National*, a *Memory Data Book* from *Sharp*, and a *Discrete Semiconductor Condensed Catalog* from *Philips*.

Free samples of their new 75ALS176 differential bus transceivers as well as their new *Widebus* family chips are available from *Texas Instruments*. The folks at *R&D Electronics* have an interesting new surplus flyer which includes cheap ultrasonic motion detectors and lots of assorted hacker project cases. A wide selection of new and used antique radio vacuum tubes is available through *Don Diers*. And, rebuilt military infrared viewers are available from *Stano Components*.

One of the more popular CAD/CAM circuit analysis programs for the high end engineering workstations goes by the name of *SPICE*. For this month's free new software, nearly all of those integrated circuits houses are crawling all over themselves to see who can get their free *SPICE* macromodule simulation disks out there firstest and fastest. Early entries include *Linear Technology*, *PMI*, and *Motorola*.

The free *Linear Technology* disk includes a simulation and macromodel of their ultra low noise op-amp we looked at last month. Additional info on *SPICE* often shows up in the free engineering design trade journals, such as *MicroCAD News*.

CASE AND PACKAGING RESOURCES

Appliance

1110 Jorie Blvds, CS 9019
Oak Brook, IL 60522
(708) 990-3484

Coburn

1650 Corporate Road West
Lakewood, NJ 08701
(201) 367-5511

Constantine

2050 Eastchester Road
Bronx, NY 10461
(212) 792-1600

DonJer Products Co

Ilene Court Building 8
Belle Mead, NJ 08502
(800) 336-6537

EDLCO

PO Box 5373
Asheville, NC 28813
(704) 255-8765

Electronic Component News

1 Chilton Way
Radnor, PA 19089
(215) 964-4345

Electronic Packaging

1350 East Touhy Avenue
Des Plaines, IL 60018
(708) 635-8800

Fomeboards

2211 North Elston
Chicago, IL 60614
(312) 278-9200

Fotofoil/Miller Dial

4400 North Temple City Blvd
El Monte, CA 91734
(818) 444-4555

Hammond

1690 Walden Avenue
Buffalo, NY 14225
(716) 894-5710

Keystone Electronics Corp

31-07 20th Road
Astoria, NY 11105
(718) 956-8900

Metalphoto

18531 South Miles Road
Cleveland, OH 44128
(216) 475-0555

Mouser Electronics

11433 Woodside Avenue
Santee, CA 92071
(800) 346-6873

PacTec

Enterprise & Executive Avenues
Philadelphia, PA 19153
(215) 365-8400

Polycase

4726 Superior Avenue
Cleveland, Ohio 44103
(216) 391-0444

Red Spot

PO Box 418
Evansville, IN 47703
(812) 428-9100

Serco

612 Commercial Avenue
Covina, CA 91723
(818) 331-0517

Vector Electronic Co

12460 Gladstone Avenue
Sylmar, CA 91342
(818) 365-9661

Vero

1000 Sherman Avenue
Hamden, CT 06514
(203) 288-8001

Zero Halliburton

PO Box 3339
Pacoima, CA 91333
(818) 897-7777

A free *Designing With Plastics; The Fundamentals* booklet is obtainable from *Hoechst Celanese*.

Turning to my own products, I am now self publishing nearly a dozen titles using my new *book-on-demand* PostScript technology. Four of these you might find interesting are the *Hardware Hacker II* reprints, (which contain all of my **Radio-Electronics** columns, updated, edited, and cross indexed), my *Ask The Guru* volumes I and II, and my brand new *LaserWriter Secrets* book-disk combo.

I've also started up a major new PostScript and desktop publishing BBS on *Genie*. Our goal is to have a thousand free downloads very soon. See you there.

Finally, I've got a new and free mailer for you which includes dozens of insider hardware hacking secret sources. Do write or call for a copy.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8-5. ♦

Don Lancaster's Hardware Hacker

July, 1990

Electronic tune chips
Unusual book resources
Ten speed blender Control
Power control fundamentals
A hacker interchange standard

As we've seen in past columns, within a decade we just may reasonably expect electronic hardware having computation abilities that are as complex as those of the human brain. Driven primarily by ultra-cheap and ultra-dense dynamic RAM technology.

Now, admittedly, my timing on this might be off by as much as twenty minutes in either direction. Things seem to be going even faster now than they were a few issues ago.

Several Japanese outfits have now actually firmly scheduled their future production of 256 Meg x 17 SIMM chips. And it appears another level of *threshold effect* just might have been crossed with the concept of *OOPS* or *object oriented programming* which is spreading like wildfire.

So how can you tune yourself into and profit from this near-term inevitability of human brain functionality?

As usual, those free industry trade journals are the answer. In this case, the *E.E. Times* is a very good choice. They are very big on dynamic RAM developments, on neuron computing, and on "fuzzy logic" in general.

Cold fusion. This is being written on cold fusion's first birthday. And according to the *Wall Street Journal* for April 3, 1990, on page B4, "a small but growing number of scientists believe they are seeing entirely new phenomenon," and "There is now a growing consensus that you can't explain the excess energy by errors." It appears, in fact, that several distinct and valid cold fusion mechanisms might be involved. Sixteen labs have recently reported fresh and positive new results.

A very interesting report titled as *Electricity by Serendipity* did appear in the *March 2, 1990* issue of *Science*. This describes a new type of fuel cell which permits the *premixing* of the hydrogen and the oxygen gases, something previously thought to be utterly impossible. These cells also involve hydrogen being absorbed or adsorbed into palladium, in cells remarkably similar to the cold fusion setups.

The obvious unanswered question is "how much of cold fusion's excess heat is really this previously unknown type of fuel cell?" And vice versa.

Our usual reminder here that most of the resources mentioned have been gathered together into the *Names and Numbers* appendix or the *Unusual Book Resources* sidebar. You can contact all the listees directly for more info.

UPDATE: As of fall 1992, the cold fusion has largely failed to prove its case. No conclusive evidence of any atomic processes have been shown to date. Cold fusion appears to have been downgraded to a laboratory curiosity having few supporters. But labwork does continue.

Let's start with a lively topic...

A New Standard For Hacker Printed Circuits

The editors at *Popular Electronics*, *Radio-Electronics*, *Probe*, *Midnight Engineering*, *Computer Shopper*, *Nuts and Volts*, *Byte*, *Audio Amateur*, and *Circuit Cellar Ink* have all been separately grappling with a common problem: How can clean and accurate printed circuit layouts get easily and cheaply put in the end user's hands?

Or dialplates, drilling templates, detailed test and debug info, software

listings, charts, or most any other tech writing or tech illustrations?

Putting any of these in the magazine does take up valuable space, and the third-generation photocopies or litho negatives you sometimes end up with are often of low accuracy and quality. And it sure gets hard to make a correction three months later on 360,000 already printed pages, some of which are buried in a lesser-known suburb of Moose Jaw, Montana.

On the other hand, the BBS downloading will only work if the sender and sendee do have fully compatible hardware and software.

What to do?

I would like to suggest an obvious solution. It is called an *EPS* file, and is short for *Encapsulated PostScript*.

An EPS file can easily handle any printed circuit layout, schematic, isometric or perspective drawing, any dialplate, or text or graphics of any sort to *arbitrarily high resolution*.

The EPS files are extremely device independent. Since an *EPS* file is an ordinary ASCII textfile, it could easily be used with *any* word processor or *any* editor with *any* brand of personal computer of *any* age and CPU.

At the output end, an EPS file can be used directly on a laser printer, by a typesetter, or by a photoplotter. With

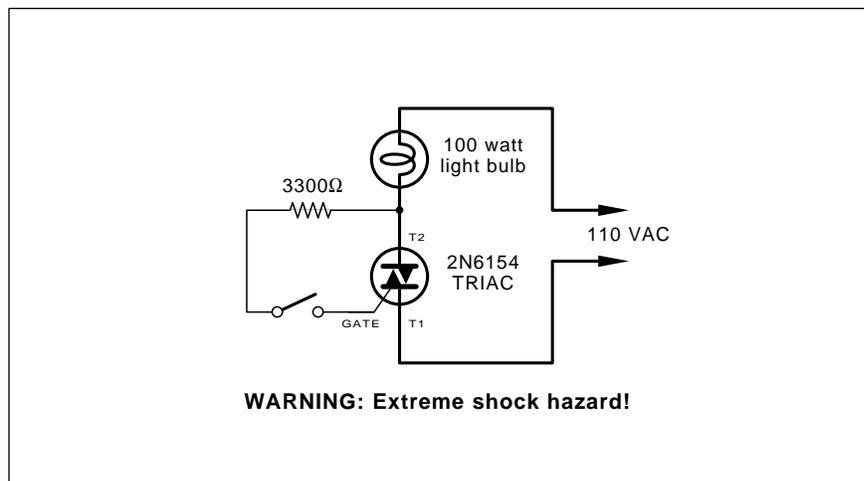


Fig. 1 – A TRIAC CAN BE USED as a line operated ac power switch which can directly control lamps, heaters, or motors. A brief and small current pulse into the gate turns the triac on; it remains on until the main current reverses.

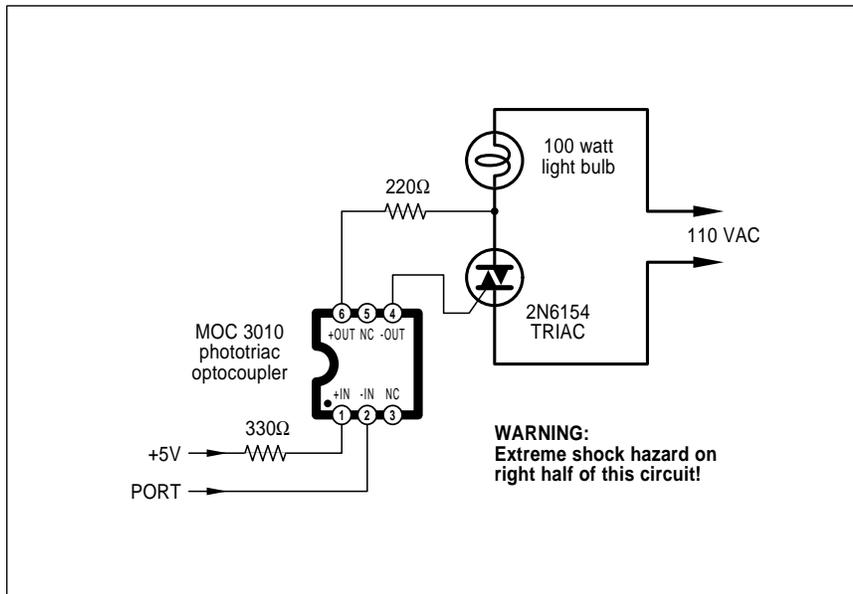


Fig. 2 – A MICROCOMPUTER TO TRIAC interface uses a phototriac optoisolator to let safety isolated logic signals directly control high power loads. Depending upon the input waveforms and the load, this same circuit can be used for either an on-off or a proportional phase control. A low input powers the lamp or other load.

simple and crude emulators such as *Freedom of the Press*, *GoScript*, and *UltraScript*, you can also print your results on ordinary dot matrix or ink jet printers, albeit to a lower resolution. The latest of fax machines are set up to directly handle *EPS* files, some to device independent resolutions that can exceed 2650 DPI. There is no high-end limit to print quality.

Better yet, practically all of those

CAD/CAM and illustration packages either now use PostScript internally or at the very least are capable of generating EPS output files.

The EPS files can also be extremely compact. For instance, a fancy circuit schematic should need no more than a 10K textfile maximum. So, EPS stores cheap and downloads fast.

But what if you are using an expensive or proprietary CAD/CAM or

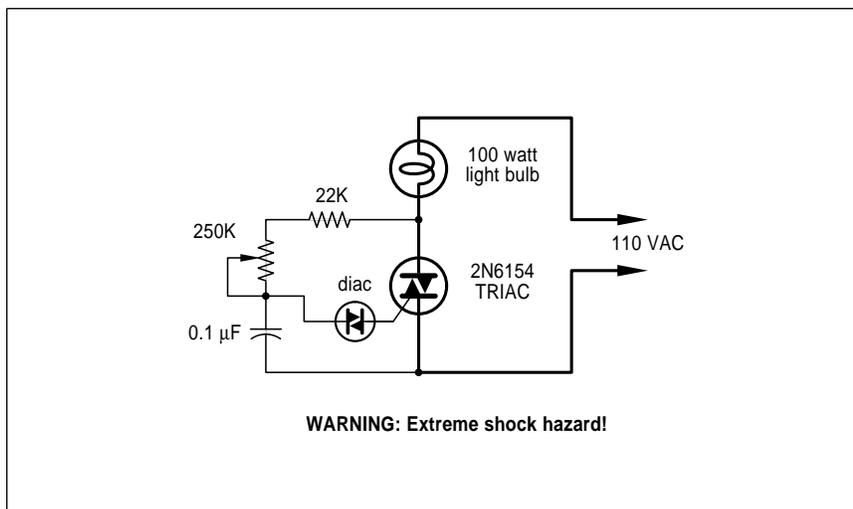


Fig. 3 – PHASE CONTROLLED DIMMER delays triac turn-on to a chosen point in each ac half cycle. Use this circuit ONLY for incandescent lamps, heaters, soldering irons, or "universal" motors that have brushes.

layout package? Surely you could not provide a free copy of these to every reader in the country, could you? Especially if you are on a Mac and they are on a PC.

There is a simple little trick you can pull that is called *pseudo-compiling*. With pseudo-compiling, you might convert any source of PostScript code into a *Just the facts, Ma'am* form that uses nothing except the simplest of put-and-place PostScript commands. Anyone can run a pseudo-compiled EPS file, and absolutely nothing will remain of the original code or the way it was generated.

Better yet, that pseudo-compiled PostScript often will run ridiculously faster than the original. And pseudo-compiling is easily and quickly done by using Adobe System's brand new and cheap *Distillery* program, by one of my *gonzo justification* routines, or your own custom code.

What about screen images? In any broad based user interchange standard, you certainly would not want to use any screen images if they hurt the device independence in any way.

Fortunately, systems using display PostScript or the display PostScript emulation are now becoming readily available, as is software that returns printer bitmaps for screen display. So are programs and applications which internally capture and display EPS.

How does an EPS file differ from an ordinary PostScript textfile listing? Actually by very little. There are a few required remarks at the start of your file plus a few optional ones. And a very few PostScript commands (such as *initgraphics*) are not allowed if they would somehow corrupt the program or system that the EPS file is being imported into. Several other obscure commands (such as *settransfer*) must be carefully saved and restored if they are altered. EPS files are also limited to a single page each, but you can use as many of them as you like.

To get started on all of this, get yourself copies of that *Encapsulated PostScript Files Specification*, v 2.0, and the *Document Structuring Conventions Specification*, v 2.1. Both of these are available free upon request through Cynthia Johnson at *Adobe Systems*, or else through one of the PostScript BBS systems. You should not create or use any EPS files without

having these two on hand.

The fundamentals on PostScript are covered by Adobe's blue *PostScript Tutorial* and red *PostScript Reference Manual*, while ready-to-use printed circuit layout, schematic, isometric, and perspective routines are found in my *PostScript Show and Tell*.

Let me know your thoughts on a standardized hacker interchange format based upon standard EPS files.

AC Power Control Fundamentals

Most hackers have observed at one time or another that your typical semiconductor will instantly vaporize if you connect it across the ac power line. Obvious problems here are that the power line is high voltage, high current, and either polarity.

One popular semiconductor that can easily be used as a high power ac line switch is called a *triac*. A typical on-off circuit is shown in figure one.

A triac has two power terminals called *T1* and *T2*, and a control terminal called the *gate*. A triac remains off until a low level pulse (usually 5 volts at 50 ma) of either polarity is applied to the gate. The triac then turns on its main terminals and remains on so long as the main current continues in the same direction.

Thus, a triac turns on very shortly after it receives a gate pulse. It stays on until the next zero crossing of the main ac current through it.

When off, the triac can block the full applied line voltage. When on, the triac can conduct several amperes with a drop of only a volt or two. A modest heatsink is usually needed to handle the current. Figure a square inch or so for each 50 watts of load.

As a long term solid state on-off switch, a triac can handle most any ac load within its current rating, and will work equally well with any style lamp, heater, or motor.

You can pick up an eight amp triac at *Radio Shack* for \$1.40, and you'll find several low cost triac selections among our many **Radio-Electronics** advertisers. Three major suppliers of triacs do include *Motorola*, *SGS*, and *Texas Instruments*. While all three have lots of triac data books and ap notes available, none could even think of holding a candle to the original and classic *GE SCR Manual*, which, sadly, is long out of print.

While triacs are fun to experiment with and easy to use, do note you are dealing directly with the ac power line here. You have an extreme, and possibly lethal, shock hazard. Always do keep one hand behind your back. Never leave power applied after a test or experiment. And always use an isolation transformer should you want to view any scope waveforms.

Figure two shows you one simple computer to ac power interface. You take a special optocoupler known as a *phototriac isolator* and use it as a safety interface. When your computer port goes low, a LED in the isolator turns on, which fires up an internal baby phototriac, that in turn whumps the main triac. This safety isolates your computer from the power line, yet still allows a small logic signal to directly control a kilowatt or more of ac line power.

Even with the safety isolation, you still have a severe shock hazard on the

right side of figure two.

Observe that this interface works backward from what you'd expect. A low input powers your load, and vice versa. This makes far better use of the micro's current sinking ports.

Under certain conditions, a triac can be used to control the brightness or speed of your power load. One way to do this is by using *phase control*, such as is shown in figure three. If you do precisely delay the gate pulse to some point in the ac half cycle, only partial ac half cycles will get through to the load. Since full power is only applied for part of the time, you end up with an average lower power sent to the load.

But note that phase control will not work with any old power load. Phase control is fine for heaters, soldering irons and other resistive loads, and is really great for an incandescent lamp dimming. While phase control can be used to control the speed of a universal ac-dc motor which uses brushes, a

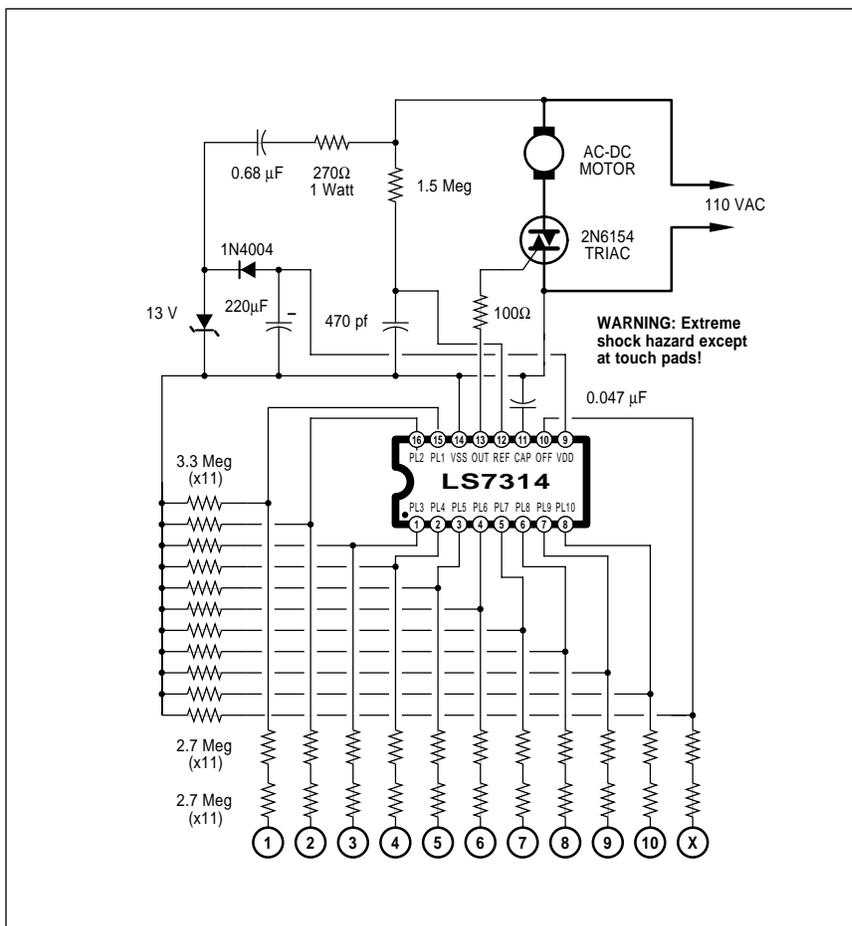


Fig. 4 – A 10-SPEED TOUCH CONTROL BLENDER circuit that uses the low cost LS7314 chip by LSI Systems. The eleventh touch pad is for power off.

slightly fancier feedback circuit that senses the motor back emf will often work considerably better.

Note that a simple phase control absolutely, positively must *never* be used with a fluorescent lamp or an ac induction motor. While it is possible to use triacs to dim a fluorescent or to control the speed of an induction motor, these need much fancier and carefully crafted circuits.

Here is how your simple dimmer control works: The *diac* shown consists of two four layer diodes back to back. It behaves sort of like a neon lamp. It is an open circuit until its terminal voltage gets up to fifty volts or so. Then it will suddenly turn on, dumping the capacitor charge into the triac gate. The diac turns back off when your capacitor is discharged. Varying the brightness control decides how fast the capacitor charges, and thus when in the cycle the triac fires.

The later in the cycle, the less the percentage of the time that power is applied to the load, and the dimmer the lamp. Since this all happens 120 times per second, the repeated off-on actions are well beyond your critical persistence of vision limit, and no flicker will be noticeable. The long thermal inertia of the lamp filament also helps

eliminate flicker.

Diac trigger diodes are usually sold by the same sources who supply triacs. These days, though, it is far better to digitally generate all the power line phase delays by either using a micro-processor or a custom power control chip. One example might be...

A Touch Controlled Blender

Certainly one of the most obscure and low profile ic chip houses is *LSI Systems*. Yet, these folks do have an outstanding selection of the low cost hacker integrated circuits. They are particularly strong in ac power controls, counters, timers, delay circuits, electronic locks and melody chips.

Figure 4 shows you their LS3714 chip as is used for a ten speed touch controlled blender. It can also be used for a ten level dimmer. Cost in singles is a mere \$2.75, dropping to seventy cents in production quantities.

There are eleven touch plates used. Touching any one sets that selected power level to the load.

Their circuit consists of a touch sensitive one-of-eleven latch which selects and remembers your desired power level. That level is converted into a phase angle which determines when to fire the main power control

triac. A reference input on pin 12 synchronizes an internal phase lock loop to the power line zero crossings.

Double resistors are used on the touch plates as a safety feature.

The active touch plate inputs can also double as LED output drivers, thus lighting one-of-ten selected LED lamps to show your current power or speed level. I have left the RFI noise filter off the output to keep our circuit simple here. You can also customize all of your firing angles to improve linearity for your selected load. Consult the data sheet for full details on these extras.

Play a Simple Melody

As an entirely different *LSI Systems* circuit, figure five does show you a LS3404 melody chip. There are 31 melodies in stock, and you can also customize your own (in large quantities) tunes up to 255 notes long.

The envelope of each note gets adjusted to an exponential decay to produce a high quality, chime-like tone. The circuit also shuts itself down at the end of each tune. The operating current is five mils. Pitch is set by the RC values at pin 5. Decay time is set at pin 3. Pin 4 sets the tempo.

Be sure to get a complete set of LSI data sheets. These folks do have over three dozen low cost chips that cry out for new hacker uses. What can you come up with here?

Unusual Book Resources

I feel that the best possible way for hackers to keep and stay informed is by aggressively exposing themselves to the industry trade journals. And the second best is through creative use of on-line access services, most especially the *Dialog Information Service*.

But technical and any other unusual books certainly have their place. As you might have noticed, mall storefronts that have a sign out front that says "book store" are often less than useless. And publisher's catalogs only carry their own titles, many of which may be "me too" or apallingly bad.

Instead, you really have to expose yourself to sources that have a vested interest in stocking a wide selection of the best books on special topics.

As your resource sidebar for this month, I have tried to show several sources of unusual books that I've

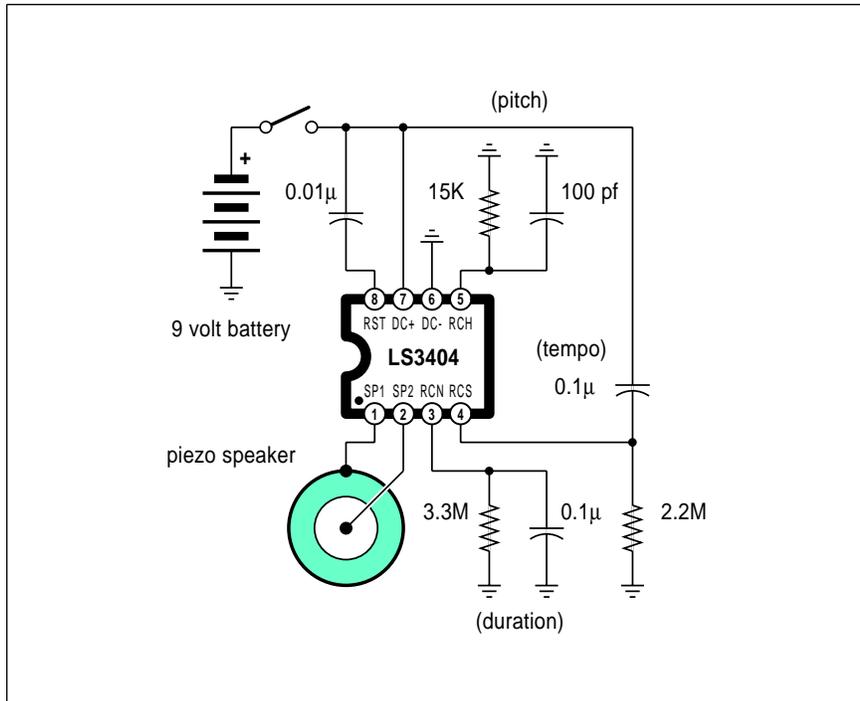


Fig. 5 – A HIGH QUALITY MELODY circuit. The slow decay waveforms create chime-like notes. Pitch, tempo, and duration are adjustable.

personally found of interest. Let's do a quick rundown...

The foremost source for hacker titles has to be *Lindsay Publications*, who do stock an amazing variety of mechanical, machine shop, antique radio, craft, and weird science titles. For automotive electronics, nobody can beat *SAE*. And for electronic music, the *MIX Bookshelf* is first rate.

For astronomy and space books, try *Frontier Space Books*. For robotics, use *Educational Products*. For all the alternate energy and self-reliance, try *Real Goods*. For establishment energy and conservation stuff, *AEE Energy Books*. For signmaking, it's *SignCraft*. For metals and properties of materials, *ASM International*.

It appears that two of the finest technical bookstores in the country are across the street from each other. So, you will want to check out both the *Stanford Bookstore* and the *Computer Literacy Bookshop*. For a direct mail source of most technical and industrial titles, you also may want to check out *Omega Engineering*.

By far the best place I've found for in-depth reviews of all unusual and genuinely useful books is the quarterly *Whole Earth Review*. I cannot say enough good things about these wonderful folks.

I try to stock my own titles and only the very best PostScript titles of others in my own *Synergetics*.

It seems I've always been attracted to what I call "Tain't Likely McGee" publications on Tesla-was-an-alien free energy, perpetual motion, Pogue carburetors, Newmann engines, and similar off-the-wall goodies. Although Lindsay stocks and honestly reviews a few of these titles, a second and more typical source would be *H&A Industries*.

As a final favorite of mine, *Singing Wind* does specialize in the Western Americana, Southwest Literature, lost mine lore, and an otherwise amazingly eclectic collection of arcania. Since *Singing Wind* has an unlisted address, getting there is half the fun. If you're not one of their kind of people, you'll never find the place.

Well, maybe one hint. Go north on Ocotillo Road out of Benson, Arizona till it feels about right. Then turn right just beyond the seventh cow. Keep the gates the way you find them.

UNUSUAL BOOK RESOURCES

Antique Radio Books 498 Cross Street Carlisle, MA 01741 (508) 371-0512	Frontier Space Books 2400 Foshay Tower Minneapolis, MN 55402 (800) 245-8627	SAE 400 Commonwealth Dr Warrendale, PA 15096 (412) 776-4841
AEE Energy Books PO Box 1026 Lilburn, GA 30226 (404) 925-9558	H&A Industries Rt 2 Box 35E Bowling Green, MO 63334	SignCraft 1938 Hill Avenue Fort Myers, FL 33901 (813) 939-4644
ASM International 9639 Kinsman Road Materials Park, OH 44073 (800) 368-9800	Lindsay Publications PO Box 12 Bradley, IL 60915 (815) 468-3668	Singing Wind Bookshop Ocotillo Road Box 2197 Benson, AZ 85602 (602) 586-2425
Computer Literacy 2590 N First Street San Jose, CA 95131 (408) 435-1118	MIX Bookshelf 6400 Hollis St Ste 12 Emeryville, CA 94608 (800) 233-9604	Stanford Bookstore 135 University Avenue Palo Alto, CA 94305 (800) 533-2670
Dialog Info Service 3460 Hillview Avenue Palo Alto, CA 94304 (415) 858-2700	Omega Engineering One Omega Drive Stamford, CT 06907 (800) 826-6342	Synergetics Box 809 Thatcher, AZ 85552 (602) 428-4073
Educational Products PO Box 606 Mineola, NY 11501 (516) 689-8409	Real Goods 966 Mazzoni Street Ukiah, CA 95482 (800) 762-7325	Whole Earth Review 27 Gate Five Road Sausalito, CA 94965 (415) 332-1716

Tellyawhat. I'm sure I've missed plenty of good sources for unusual books. For this month's contest, just tell me about some other genuinely useful place to find specialized or oddball titles. Do include a mailer if possible. We will have a dozen *Incredible Secret Money Machine* book prizes, along with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best.

As usual, send all of your written entries directly to me at *Synergetics*, rather than to **Radio-Electronics**.

New Tech Literature

Free data books for this month do include the *Product Selection Guide* from *NEC* on memory, micros, peripherals, and telecom chips; the *i486 Microprocessor from Intel*; the new *Semiconductor Databook and Application Notes from Unirode*.

Two surplus catalogs having great pricing are available through *Hosfelt Electronics* for electronic goodies; and *Surplus Center* for lots of pneumatics, hydraulics, and larger motors.

Compliance Engineering is an unusual trade journal aimed at helping you meet FCC and similar specs. They

have a free supplement *Direct Connection: Interfacing to the Telephone Network* available just for you. Ask for Application Note #102.

Reasonably priced vacuum forming machinery is available through *Ron Charles & Associates*. While intended for hobby modelmaking, there should be lots of hacker uses involving prototypes and limited production runs.

Two interesting new prototyping and model materials are the *Komacel* and *Celtec* foamed vinyls. Some free samples are available.

Turning to my own products, I've put together a special new *Lancaster Classics* package of six of my finest hardware books plus that complete *Hardware Hacker II* reprint set which covers everything which has appeared in these RE columns.

Finally, I've got a new and free mailer for you which includes dozens of insider hardware hacking secret sources. Write or call for info.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8-5 in *Mountain Standard Time*. Let's hear from you. ♦

Don Lancaster's Hardware Hacker

August, 1990

Huffman Codes
Video Line Drivers
Run Length Encoding
New Compaction Chips
Amateur Radio Astronomy

There's a pair of stupendous new high end compaction breakthroughs for this month, so I thought it might be a good time to go over some of the fundamentals of...

Data and Image Compression

You can compact data or an image whenever you want to store it in less space or else transmit it in less time. The process of compaction is sometimes called *compression*, while the reverse process is called *restoration*, *expansion*, or *regeneration*.

A compression scheme is *noiseless* if it does not add anything in the way of artifacts to your output data string. A scheme is *lossless* if nothing gets removed and if the recovered data is *exactly* the same as the input data. Being both lossless and noiseless is obviously important if you're dealing with electronic funds transfer. On the other hand, slight video image quality variations to that tapioca pudding scene in *Godzilla versus the Night Nurses* will usually not be noticeable. Even to the critical reviewers of this cross-genre classic.

A compression scheme is in *real time* if it keeps up with tv frames or movie film, or else if less than one second of delay is needed for a user interaction. The compression is *symmetric* if the same amount of time and hardware is needed for either a compaction or regeneration.

The *compression ratio* is simply how much compaction you gain. If you reduce a 100 K textfile to 12.5 K, your compression ratio is a big 8:1. Similarly, a 20 percent compression reduces your file size by 5:4.

As you might suspect, a modest amount of compaction, perhaps 30 percent, is easy to do. Things do get sticky fast after that. The higher the compression ratio, the more time and effort that is required to do the job.

Naturally, there is a fundamental limit to the ultimate achievable compression, based upon information theory and on entropy constraints. Because both the English language

and typical pictures are extremely *redundant*, these limits often end up surprisingly generous.

But do note that the less redundant the information, the more intolerable any errors will become. Further, any simple errors tend to become far more destructive.

For instance, any uncompressed error which misspells any single word could instead totally trash your entire message in your compacted file. This error intolerance, along with the long processing times, are the two serious tradeoffs that get involved in extreme compaction.

Compression schemes which are *content dependent* are often (but not always) more effective than schemes that can accept anything as an input. In general, the more you know about what you want to compress, the more you can squash it. For instance, the compacted data string *alincgburgadd* should not take you four score and seven years to expand into its full text version, especially if you have got a library handy.

Or, as a second example, you could use a city, state, and a zip code consisting of the single digit 0 for your own town in a local mailing list.

Several popular areas of compression interest include ASCII text strings, fax printouts, delta modulation, disk data formats and full color HDTV video images....

Text Compression

Eight bit bytes of 256 states are a wasteful way of showing ASCII text letters, which at the most needs 127 characters, and often require only 26. Early *Infocom* text adventures used a scheme which crammed three ASCII characters into a pair of 8-bit bytes, a compression to 67 percent. Which also made any snooping for hints real tough. The *Adams* adventures instead used some character pairs. The most commonly used occurrences of two characters got placed in unused code slots, again giving you something like a 3:2 compression on the average.

In spelling checkers, the words are most often arranged alphabetically. Since each new word will share many initial characters with a previous one, you could provide a leading number instead. For instance, to get from *fixation* to *fixative*, the second word could be coded as *6ve*. You can also apply character pairs as well as a trailing byte that could represent the

Symbol "A"	that is 20%	likely codes as 10.
Symbol "B"	that is 18%	likely codes as 000.
Symbol "C"	that is 10%	likely codes as 011.
Symbol "D"	that is 10%	likely codes as 110.
Symbol "E"	that is 10%	likely codes as 111.
Symbol "F"	that is 6%	likely codes as 0101.
Symbol "G"	that is 6%	likely codes as 00100.
Symbol "H"	that is 4%	likely codes as 00101.
Symbol "I"	that is 4%	likely codes as 01000.
Symbol "J"	that is 4%	likely codes as 01001.
Symbol "K"	that is 4%	likely codes as 00110.
Symbol "L"	that is 3%	likely codes as 001110.
Symbol "M"	that is 1%	likely codes as 001111.

Fig. 1 - A HUFFMAN COMPRESSION USES SHORT CODES for often occurring letters or symbols, and longer codes for those less often used. On the average, your overall message will end up shorter. Here is a simple example code which involves thirteen symbols.

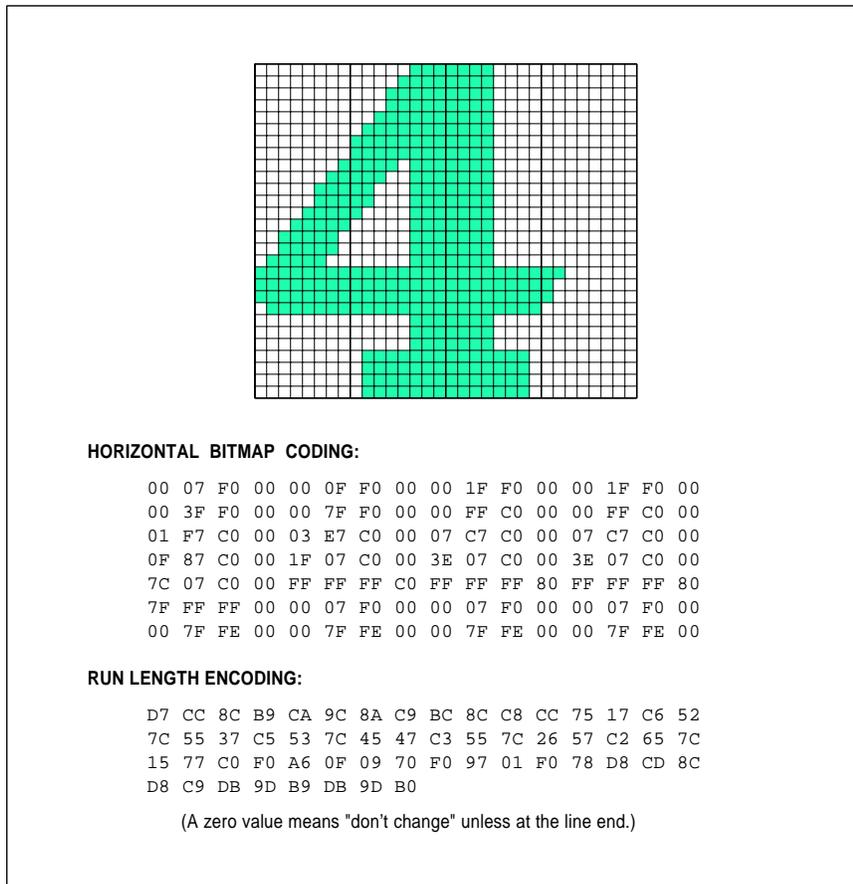


Fig. 2 – RUN LENGTH ENCODING IS AN EFFECTIVE compression scheme for black and white images. In this example, four bit bytes representing how many white or black pixels replace the bitmap for a 2:1 compaction.

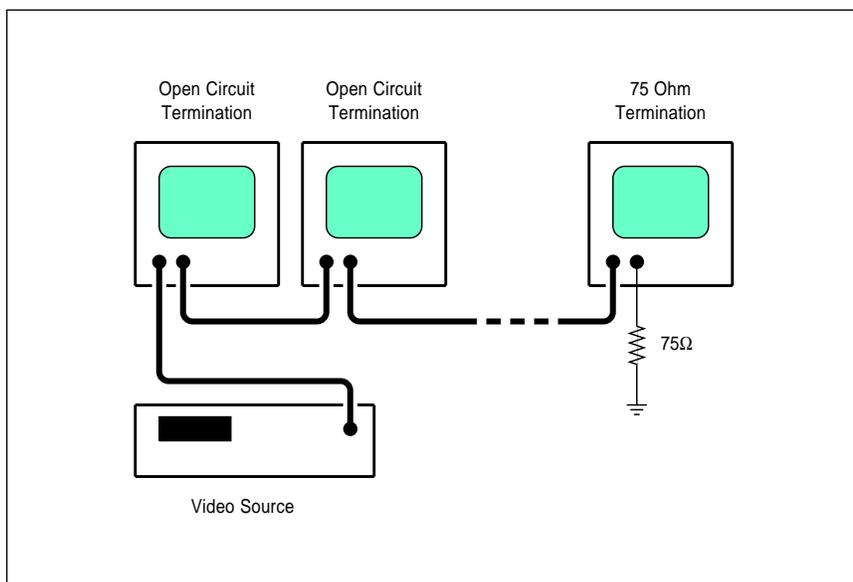


Fig. 3 – THE CORRECT WAY TO CONNECT several video monitors to a single source is to daisy chain them. Only the last monitor in parallel should be terminated with a 75 ohm resistor. Never connect cables in parallel!

256 most popular combined ways of ending words, *s*, *ing*, *ly*, *ed*, and so on. When all is said and done, it takes only slightly over 9 bits to represent an average English word in a spelling checker dictionary.

Advanced compaction schemes often are first described in the *Communications of the ACM* from the *Association for Computer Machinery*.

Going to a non-ASCII interpretive code can also help you bunches. For instance, to describe a single curved portion of a PostScript character, six signed integers, seven spaces, and the word *curveto* get involved. For a total of around 42 characters.

In Adobe's Type I Fonts, a special *character string* code gets used, of which 32 entries are commands, and the rest signed numerics of one or two self-spacing bytes. Typically, only six bytes will be needed for the same *curveto* example, giving you a compaction of 6:1 or so. More details in Adobe's Type I Font black book. I do have a few of these in stock.

The ASCII letter "e" usually needs eight bytes for transmission. So does an ASCII "z". But the "e" gets used far more often. So, why not set up a code where an "e" needs four bits, while a "z" needs fourteen? On the average, all of your text messages will end up somewhat shorter.

Such a scheme is called *Huffman coding*. The original horse's mouth document is *A Method for the Construction of Minimum-Redundancy codes*, as found in the September 1952 *Proceedings of the IRE*.

An example of a Huffman code appears in figure one.

Huffman codes are based upon making the length of a character code inversely proportional to the popularity of that character's use. The good news here is that a Huffman coding is fairly fast and simple, and often can be applied in combination with other compaction techniques. The bad news is that a variable bit length word can be awkward to handle in an 8-bit or 16-bit micro, and that the total compaction you get is often rather modest and typically in the 20 percent range. Worse, errors under a Huffman coding do tend to trash the entire message, rather than a single word or two.

Variations and improvements on

this scheme are known as the *modified Huffman codes*. These are in no way limited to ASCII. Any place you have symbols with different probabilities, you can use variable length codes to your advantage. Often, your message will first get analyzed, and a set of rules in the form of a dictionary will get sent as a prolog. Matching the coding to the message usually will give you the optimum compaction.

Fax and the Printed Page

Most fax images and most printer output consists of little bits of black buried in a sea of white. Obviously, a bitmap that sets aside one bit for each black or white dot is horrendously inefficient most of the time.

One popular way around this which works exceptionally well with black and white images is called *run length encoding*. With run length encoding, each successive byte represents *how many* black dots or how many white dots are to follow. For instance, four bytes in a bitmap could only represent 32 pixels. But those same four bytes coded -18- -56- -9- -143- could now represent a string of 226 pixels, a 7:1 compaction. In this case, the first 18 pixels would be black, followed by 56 white ones, followed by 9 black ones, and a final 143 white ones.

Figure two shows you a simple example of run length encoding.

Should you have lots of picture detail, popular run length encoding schemes will automatically switch back to a bitmap whenever bitmaps are more efficient. The code can also be extended to allow for any identical sequential lines.

In PostScript, the first time your descriptive font character is used, that character gets converted into a bitmap and then placed into a *font cache*. Repeated use of the same character becomes much faster, since you are now only moving a bitmap using a *BitBl* operator, instead of generating fancy paths. On up to a certain size, "real" bitmaps are used. Above that size, run length encoding is used to minimize the storage needs. While run length encoding in PostScript is typically six times slower than using a real bitmap, it is many hundreds of times faster than using the original character description.

Most modern fax machines use what is known as a *Group III* compression, which is based largely upon run length encoding. One source of circuits and info on Group III compression is *American Micro Devices*, especially their new AM95C71 video compression-expansion chip set.

But the best way to compress a fax image is to flush it and use PostScript instead. Besides offering you a ridiculously better image quality, most PostScript superfax images transmit in one-tenth the time and will store in one-tenth the space.

Doing The Obvious

One obvious way to compress files is to not send what you don't need. Eliminating all comments and REM statements from programs at run time is a typical example. So is getting rid of any extra spaces used for pretty printing. In PostScript, careful use of persistent downloads and common dictionaries can very much reduce the individual file sizes.

Another way to really compact certain types of images goes by the name of *delta modulation*. With delta modulation, you only transmit the *changes* between what you have now and what went by previously.

Animation is one obvious example. I've had one of my students do some incredible 4-stroke engine animation

on the Apple IIe simply by the brute force coding of only frame-by-frame changes in successive pictures.

But delta modulation really shines for sound synthesizers. To compact voice or music, you try to anticipate where the sound is going to be in the next sample, and then transmit only the value *difference*.

This is known as *linear predictive coding*, and the sound toolkits on the Macintosh and the Apple IIGs include lots more detail. A typical compression is 2:1 or 8:3, depending on the acceptable quality.

I use an even sneakier form of delta modulation to speed up PostScript. Say you have a shipping label or a business letter with a fancy letterhead and a digitized signature. Instead of retransmitting the entire image each time, you will simply place the total image into your PostScript printer *once* and then print the first name and address. You'll then erase *only the name and address*, and then print up your second name and its address, repeating until your entire mail list or whatever is finished. The same idea works well with forms, or anywhere else a long makeready time can be shared among many different copies.

The Disk Breakthrough

Most floppy and hard disk formats are surprisingly wasteful of disk

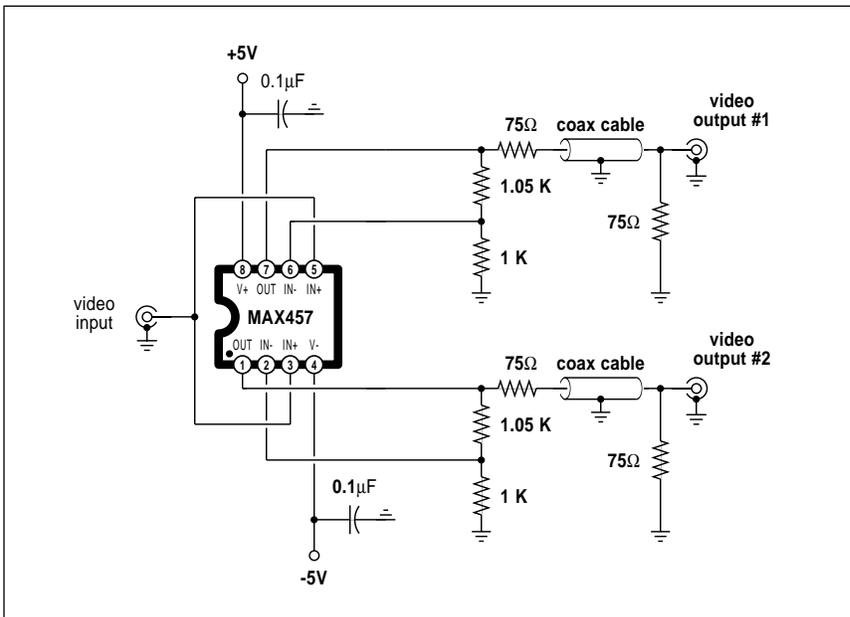


Fig. 4 – THIS DUAL VIDEO DRIVER is handy any time you want to use more than one monitor with a VCR or a computer, especially with long cables.

space. So, there are lots of possibilities here, over and above the obvious of trying to increase the number of tracks or the number of bytes per track.

Knowing exactly how your disk space is organized can often save you bunches of bytes. As one ancient example, leaving off those last eight invisible bytes of an Apple II HIRES image saved you an entire DOS disk sector per picture.

In ProDOS, a 511 character textfile requires only one sector, while a 513 character one needs *three* sectors, one for the first 512 characters, a second for the new index block now required in your switch from a *seedling* to a *sapling* file, and a third for the final data actual byte.

In fact, you can save at least one sector anytime you can get your file size just under a multiple of 512. Full details in the *Beneath Apple ProDOS* from *Quality Software*.

On the Mac, removing any unused resources from your System files can often free up surprising amounts of disk space. This becomes especially critical on earlier Mac versions with limited RAM

Similarly, knowing how your disk files are arranged and stored on any system can sometimes save you quite a bit of space. Especially on a disk that is nearly full and needs room for one or two more short files.

Our first major compression chip breakthrough for this month is the IC-105 co-processor from *Infochip Systems*. This one is initially intended

for the MS/DOS world and gives you an average of a 3:1 or higher compaction for disk files. And does so while remaining fully noiseless and lossless, and still allowing a full random access. Compression is real time up to 2 Megabytes per second, and the decompression blazes along at a 5 Megabyte per second rate.

An adaptive algorithm is used that senses the type of data and creates optimum data dictionaries for each type. A *Markoff* scheme is used.

Interestingly enough, you do not have to store these data dictionaries. They will automatically build themselves up during the decompression process. Image compression can go as high as 15:1. The initial cost is in the \$200 range.

The obvious first use for this chip is for tripling the disk storage on any laptop computer. It will be interesting to see how error tolerable this new technique is. This should end up a real winner if it performs reliably enough in the real world.

The Image Breakthrough

But the really big development this month is the CL550A chip by *C-Cube*. This beauty handles a full color video compression from any source to 33:1 and beyond *in real time*, up to and including 60 frame per second HDTV! A massive 300:1 parallel pipelining is provided through an unusual architecture. The action takes place at a previously unheard of ten *billion* operations per second.

This compression gets done by making what are known as *Discrete Cosine Transforms*. These involve blocks of 64 pixels. It turns out that certain spatial frequencies and some color shifts are nearly invisible to the human eye, so a careful filtering gets done to throw out anything that you aren't going to be able to see anyway. Your final results are virtually the same as the original. You can adjust the compression ratio for a higher or a lower final overall quality.

Best of all, this chip implements what is soon to be an international JPEG (Joint Photographic Experts Group) image standard, so it is in no way proprietary or linked in any way to any particular technology, media, transmission, or image format. Which should finally blow that abortive DV-I

atrocious out of the CD-ROM water.

The obvious uses include genuine multimedia for personal computers, compact full animation on CD-ROM and for squashing those bandwidths needed for HDTV broadcasts to well *under* those currently being used for plain old tv.

C-Cube does have a free technical info packet for you on their products, along with demo boards and software emulators. Projected pricing of their chip is in the \$95 range.

Video Distribution Amplifiers

There are lots of times when you might like to drive more than one video monitor from a single source. Unless you are very careful, you will get disappointing results. Fortunately, there's a brand new low cost MAX457 chip from *Maxim* which greatly simplifies this task.

Video is normally routed through shielded cables. These cables have a distributed series inductance and a shunt capacitance which makes an infinite length of them appear as an ordinary resistor. This resistance is called the *characteristic impedance*, and is often 75 ohms or so.

If you try to intentionally open- or short-circuit a cable, whenever a pulse or other signal gets to the end, it will reflect and bounce back to the source. At the frequencies associated with television, amateur radio, and CB, such a *mismatch* could cause *standing waves* and a loss of power. Thus, at these radio frequencies, *all* cables must be terminated at both ends with a resistive load equal to their characteristic impedance.

At the much lower baseband video frequencies, reflections off a short cable may not be all that bad. As a crude rule, if the cable is ten feet long or shorter, you can often get away without terminating it. Longer than that, and you will want resistive terminations at both ends, or you will get character smearing and other loss of quality.

Figure three shows you the correct way to tie several monitors to a single source. You can use a daisy chain connection. The monitors inside the chain should all be set to their *high impedance* termination stage. The last monitor in the string should get load terminated. Termination usually gets

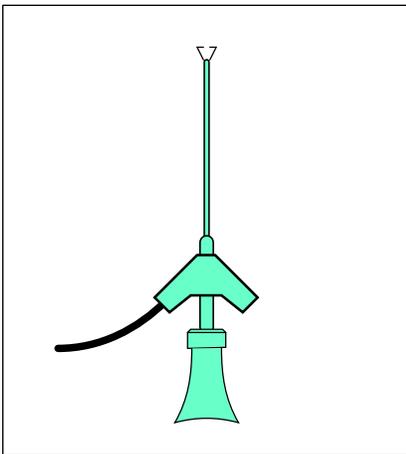


Fig. 5 – THIS NEW SMT GRABBER offered by Tektronix has a bendable snout. Free samples are available.

selected with a switch near the video input on the monitor or display.

Note that you cannot simply put a bunch of monitors in parallel, since all of their loads will gang up and swamp your source, leaving you with a very washed out picture, poor sync, or even nothing at all.

Many of the video output stages on personal computers are rather wimpy and don't take at all lightly to long cables, especially parallel ones.

Instead, figure four shows you a dual video driver using the MAX457. Each output is an independent 75 ohm source. You can cascade as many of these as you need to.

To make up for the drop across the 75 ohm source resistance, the video gain is set to precisely two. Half of this develops across the source, and half across your terminating load. At this gain of two, the bandwidth is around 30 megahertz, so any high definition stuff can be handled as well as ordinary video. For local HDTV use, the open loop bandwidth is 75 Megahertz.

A split +5, -5 supply is required. Sorry about that, but you do have to somehow suck out current on all your grounded sync tips. Supply current is under 40 mils for the pair of drivers. The normal output level is adjusted to a white level of 2 volts and grounded sync tips. This becomes a standard one volt video after the drop across the source resistor.

Naturally, you must not rats-nest breadboard any 75 Megahertz video amplifier. Use a clean double sided printed circuit layout with extensive ground plane areas and a thorough supply bypassing, or instabilities and oscillation are nearly certain to result.

Other uses do include driving A/D converters. Please let me know what unusual applications you can think of for this great new circuit.

Radio Astronomy Resources

As our resource sidebar for this month, I've chosen to round up some stuff for amateur radio astronomers.

Two of the foremost resources are Bob Sickels and Jeff Lichtman. Bob runs *Bob's Electronic Service* and publishes the *Radio Observer* magazine. He also stocks parts and kits for low noise amplifiers, microwave electronics, chart recorders, and lots

AMATEUR RADIO ASTRONOMY RESOURCES

Amateur Radio Astronomers

247 North Linden Street
Massapequa, NY 11758
(516) 798-8459

Astrophysical Journal

PO Box 37005
Chicago, IL 60637
(317) 753-3347

Bob's Electronic Service

7605 Deland Avenue
Fort Pierce, FL 34951
(407) 464-2118

Jeff Lichtman

1425 Parkmont Drive
Roswell, GA 30076
(404) 992-4959

Nasa Tech Briefs

41 East 42nd Street Ste 921
New York, NY 10017
(212) 490-3999

NRAO Observatory

PO Box 2
Greenbank, WV 24944
(304) 456-2011

Science/AAAS

1333 H Street NorthWest
Washington, DC 20005
(202) 326-6400

VLA Astronomy Site

PO Box "O"
Socorro, NM 87801
(505) 772-4011

of similar stuff. His free catalog also has a good no-nonsense intro.

Jeff has published three classics in the field which include his fine *Radio Astronomy Handbook*, *Solar Radio Astronomy*, and his *Microwave Radio Astronomy*. All well done.

A leading amateur astronomy club is apparently the *Society of Amateur Radio Astronomers*. Their \$20 yearly membership includes a newsletter.

Publications providing radio astronomy info in them include *Science*, the *Astrophysical Journal*, the *NASA Tech Briefs*, and the old *IEEE Radio Astronomy Transactions*.

Two radio astronomy sites which welcome visitors are the *NRAO* observatory located in Greenbank, West Virginia, and that *VLA* site in New Mexico. The *VLA* (very large array) is sort of in my back yard, so stop in and visit when you get there.

That *VLA* is situated within the Magdalena-Pietown-Quemado metro area. Just take the loop thruway past the theater and industrial districts. Then turn left at the fourth cow. The *VLA* is one of the most spectacular scientific installations anywhere in the world.

What about ET watching? Because of all the potential kook aspects and professional credibility, SETI activities are not normally the main focus of most serious amateurs.

Serious extra terrestrial intelligence searching needs incredibly complex hardware and rigorous elimination of locally explained sources, not to men-

tion a gonzo supercomputer or two, a thorough understanding of the cross correlation functions and Fourier transformation, and a zillion acres of land in a low-interference locale.

But you are certainly encouraged to try. That's what hacking is all about. When you make contact, be sure and say Hi for me.

New Tech Literature

Useful new data books include a *Voice Synthesis LSI* and *Telecom LSI* volumes from *OKI*; *Microwave Transistors* from *Phillips*, *High Speed CMOS Logic* from *Sam-sung*; *Optoelectronics and Image Sensors* from *Texas Instruments*; and *A/D & D/A Converters* from *Sony*.

Toni Patti of the *Cryptosystems Journal* offers some newly revised free Lorenz attractor "Owl's Mask" chaos theory programs when you send him any formatted IBM disk. Included is a powerful set of new 3-D graphics routines. Other free software includes a *Selectrim* trimpot selector from *Bourns*; and a new *PowerMOS* power transistor disk from *Phillips*.

A free sample from *Tektronix*? Welcome to the nineties. They'll be happy to send you a free sample of their new SMT grabbers. As figure five shows us, this is a small and an easy-to-use test glomper you'll find handy for most any electronic testing, surface mounted or otherwise. The tips are even bendable to reach into tight spots.

Let's hear from you. ♦

Don Lancaster's Hardware Hacker

September, 1990

Perpetual Motion
Audio Log Voltmeter
Independent Research
The Magnetocaloric Effect
Refrigeration Breakthrough

It's not at all obvious to me why we need all of the foot dragging, infighting, and squabbling going on today over HDTV high quality video display standards. It seems that several government agencies are now battling each other to win the coveted role of chief obstructionist.

To me, it is entirely obvious that HDTV *will* use square pixels, *will not* have interlace, *will* make use of fully programmable, instead of hard-wired (single standard) receivers and displays, *will* be totally digital, *will* use real time JPEG compression, and *will* follow Japanese standards.

It is also totally obvious to me that terrestrial broadcasting will serve a negligible to totally vanishing role in HDTV, while the computing, satellite, VCR, and cable uses will overwhelmingly dominate. And any intermediate or interim transition steps will prove to be a monumental waste of time and money, done by the wrong people for the wrong reasons.

So, let's just ban the networks and the feds from *any* HDTV input whatsoever, and then get on with it. They are the enemy, not Japan.

Our topics this month range from the ridiculous to the sublime...

Some Thoughts on Perpetual Motion

It may be the New Age nineties, or just a sunspot cycle peak, but a surprisingly enormous number of all you hardware hackers are busily at work building your own perpetual motion machines. I simply cannot believe the number of helpline calls and visitor drop-ins I am getting on this.

Since perpetual motion is certainly real as far as both its history and its ongoing activities are concerned, we should take a brief look here.

I guess I was in the seventh grade when I built my first perpetual motion machine. Figure one shows details. I took a gyroscope and hung several magnets on it so that like poles faced each other. The magnets were at an angle so that repulsion would have a tangential component. As the poles

repelled each other, this gyroscope would accelerate.

Or so I thought at the time. Very strangely, that gyroscope locked up instead of spinning. Seems it latched itself into a minimum reluctance field position and just sat there.

These days, I guess I don't really understand why perpetual motion is desirable. Since unlimited free energy would hasten the entropic heat death of the planet, perpetual motion is both environmentally unconscionable and socially reprehensible.

The first thing we should do to a successful perpetual motion machine designer is to stake them to an anthill. And leave them there until the next meeting of the steering committee.

Nonetheless, perpetual motion is a fascinating topic. Several very good books on this subject are available from *Lindsay Publications*, while a few of the more interesting ongoing perpetual motion scams are available to you through *H&A Industries* or the *Tesla Book Company*.

After working with quite a few of them, the perpetual motion buildees these days all appear to share several

common traits. None of them have ever attended an introductory college physics course, or else they seem to have slept through it.

While all of them claim they "just can't find anything at all" on their idea, they studiously go out of their way to avoid doing any real or honest library research. As we've found out a few times in the past, any hardware hacker anywhere can instantly get the very latest scoop on anything by way of the *Dialog Information Service*. We will see more on this shortly.

A disproportionate number of the perpetual motion buildees seem to belong to one particular religion that happens to be very big on faith and on self-reliance.

There's often a very heavy dose of paranoia, usually aimed at the patent office, a local university, all the oil companies, Detroit (which could not possibly suppress anything except quality or profits), an ex-boss, or else "them" in general.

Almost always, the buildees think *linearly* instead of *cyclically*. Thus, while a power stroke of the repelling magnets or their freezing milk bottle

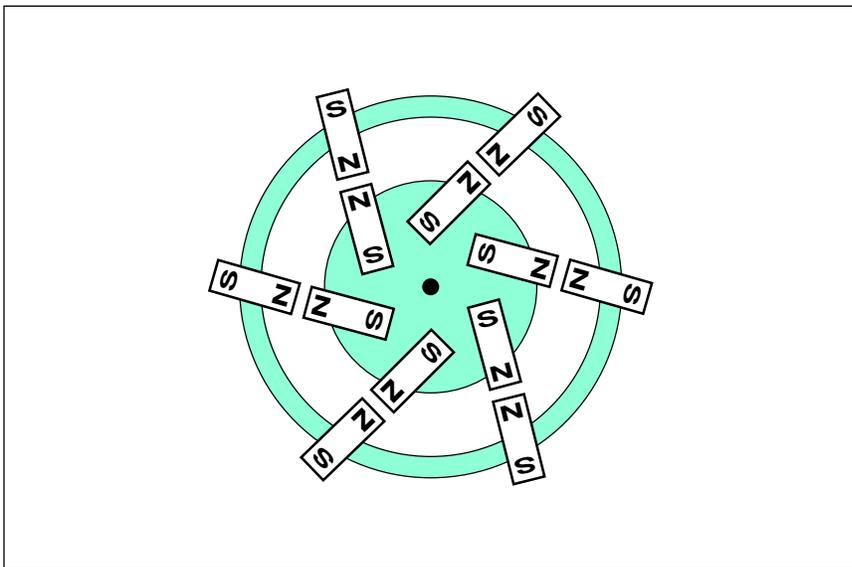


Fig. 1 – MY VERY FIRST PERPETUAL MOTION MACHINE. As the like poles of the magnets repel each other, they accelerate the rotor on a gyroscope. Sadly, it latched, rather than speeding up. But maybe if I used stronger magnets and better bearings...

- (1) - If you can't find it, you ain't lookin.
- (2) - Research is a continuous activity done on a total lifestyle basis. You cannot turn it on and off at will.
- (3) - Anticipate what you are going to research in the future and get started on it long ahead of any actual or possible need.
- (4) - Your own personal resource file should be your first and foremost starting place. Your begining file should fill at least eight cubic yards, and should expand from there.
- (5) - The free trade journals are far and away your most important external resource. A complete listing appears in *Uhlricht's Periodicals Dictionary*. Use those bingo cards!
- (6) - The *Dialog Information Service* at your local library can instantly find anything for you from anywhere at anytime.
- (7) - Other important library resources are the *Science Citations Index*, the *Thomas Registry of Manufacturers*, Interlibrary loan, the *UMI* reprint service, and the *Encyclopedia of Associations*.
- (8) - Form an extensive network of contacts outside of your circle of family, friends, or work associates. Clubs, helplines, and BBS systems are ideal for this sort of thing.
- (9) - Let your subconscious be your guide, starting from fundamental principles and guidelines. Go with the vibes.
- (10) - Quest *tinajas*.

Fig. 2 – SEVERAL OF MY INSIDER SECRETS on independent research.

makes a lot of sense to them, they will usually ignore all the repetitive and cyclic energy supplying stages needed to get to that step.

There's also the *cosmic cupcake syndrome*, the *few chips shy of a full board* affliction, and the *boy a whole flock of them flew over that time con-*

cept. But we need not get into any of these here.

Finally, there is the *magic bullet*. Their idea almost but not quite works. So, all we'll need to fix it are better gears, stronger magnets, a larger milk bottle, or a different rear axle ratio.

Or more bucks for research.

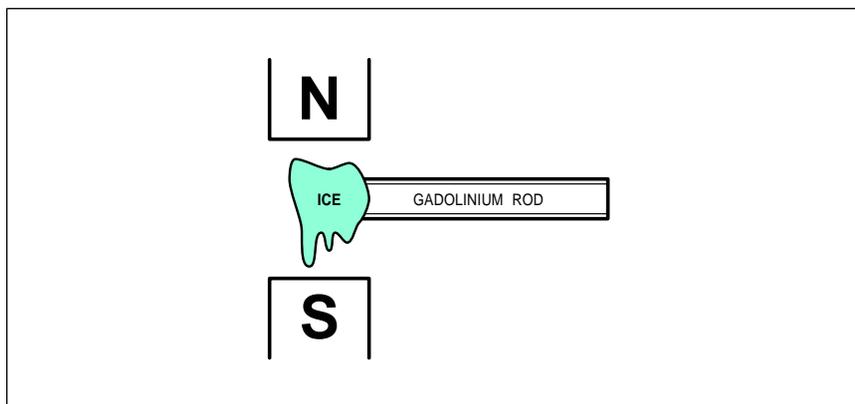


Fig. 3 – THE MAGNETOCALORIC EFFECT, very greatly oversimplified. Gadolinium and other rare earth alloys can absorb heat energy when in the presence of a magnetic field and release it otherwise. The efficiency can be as much as 40:1 better than mechanical cooling. Magnetic refrigeration is usable over an absolute zero to above room temperature range. Important first uses will likely be in cryogenics, superconductivity, liquified gases, and for hydrogen fuel research.

Several of us folks around here at **Radio-Electronics** editorial have now somehow gotten some silly ideas into our collective heads. For some unbeknownst reason, many of us presently feel that...

(A) Neither matter nor energy can be created or destroyed, except by an atomic process.

(B) Available energy always seems to convert itself from higher quality forms into lower and less useful ones. Not once have the dishes ever washed themselves. Nor have those pool balls ever re-racked by themselves.

(C) Nearly all physical and electronic processes will end up producing unrecoverable low grade heat energy, usually through friction or electrical resistance.

(D) Despite a house-senate compromise committee, congress is not expected to repeal the three laws of thermodynamics this session. Paraphrased, these three laws are (1) You can't win; (2) You can't break even; and (3) Yes, the dice are crooked, but it is the only game in town.

I guess one of the reasons some of us around here feel this way is that not once in the history of hardware hacking has even one reproducible counterexample to these silly ideas of ours ever gotten successfully and unarguably demonstrated.

Naturally, you are free to agree or disagree with us as you wish. But if you disagree, we do make only one simple request: Provide us with an experiment that can be *independently* duplicated by *disinterested* outsiders which causes your effect to show up at least reasonably well.

Then we will all believe.

Doing Serious Research

So, what is the best way to research any topic? I don't know how many calls and letters I have gotten from people which live in such a "remote" area and will claim that "absolutely nothing" is available locally. Believe it or not, one of these letters was from Cambridge, MA and yet another was from Palo Alto, CA.

Well, I have been sitting right here watching Gila Monsters on this sand dune smack dab in the middle of the

Upper Sonoran desert for nearly two decades now. Although almost everything I do is local (and much of it is done underground or in mountaintop wilderness areas), I have had zero problems whatsoever in handling top quality research on all kinds of very rewarding and well-paying topics.

So do not give me any "remote" bull. Admittedly, my tiny and isolated town of 2400 now does have its very own symphony orchestra. But that is another story.

Figure two lists a few of my key secrets to doing independent hacker research. The overwhelming reason you cannot find something is because you are not looking. You are instead going through several inept motions and keeping yourself busy, instead of taking obvious steps and handling all of them in a logical manner.

Research is not an activity that you turn on or off. Instead, you put yourself in a *continuous* research mode in which you gather and collect *everything*, needed or not, or expected or not. Never mind which topic. Your subject does not matter in the least, because chance favors the prepared mind. Thus, your very own personal resource file is far and away the most important place to look, should any specific need come up.

Set a minimum goal of eight cubic yards for your personal resource files. At least for a bare bones startup. Then let it grow from there.

Your foremost outside resource should be all of the trade journals. I subscribe to over 400 of them. As we have seen in the past, all fields do have all their own private technical magazines which are intended for a select group of insiders. Most of these are free, provided you tell them what they want to hear on their qual cards. Many include bingo cards, annual directories, and tech info.

Naturally, you'll circle everything even remotely useable on the bingo cards. If in doubt, circle it. If you do not personally rent the largest box in your local post office, you've missed the point here completely.

Electronic trade journal examples include *EE Times*, *Electronics*, *EDN*, *Electronic Products*, *Electronic Design*, and dozens more. We'll look at these names and numbers in some future sidebar.

For now, you go to the library and view the Hacker's Holy Grail, that is otherwise known as the *Uhlricht's Periodicals Dictionary*. This single hardware hacking resource is far and away more important than all of the rest put together. Use and enjoy.

The second most important outside Hardware Hacking research resource is the *Dialog Information Service*. It's also at your local library. For a small fee, *Dialog* will instantly research anything, anywhere, anytime. As an example, we'll shortly be looking at magnetic refrigeration. To get from knowing virtually nothing on this topic to having eighteen of the most recent worldwide key abstracts in hand took me seven minutes and cost me a total of \$27.57.

There's lots of other goodies in the

library, should you snoop around in enough nooks and crannies. In general, the *least* valuable things in any library are its takeout books. There's that free *Interlibrary Loan Service* which lets you pick up anything from anywhere, and the faster *UMI* service which could get you any reprint of anything provided you know the exact title, journal, and pages. For much less than *Dialog*, so long as you don't mind waiting a few days.

There's also a *Thomas Registry of Manufacturers* that lists who makes everything, but I've found this to be of limited utility. Also, check into the *Encyclopedia of Associations*, and, if you can't locate *Uhlricht's*, then the *International Standard Periodicals Dictionary* is almost as good.

Another library favorite of mine is

Magnetocaloric Effect in Strong Magnetic Fields

A.M. Tishin, *Cyrogenics (UK)*, February 1990, v30 #2, pp 127-136.

Magnetocaloric Effects in Rare Earth Magnetic Materials

A.S. Andreenko, et. al., *Soviet Physics (USA)*, August 1989, v32 #8, pp 649-664.

Magnetocaloric Effect in Thulium

C.B. Zimm, et. al., *Cyrogenics (UK)*, September 1989, v29 #9, pp 937-938.

Magnetic Refrigeration

Superconductivity Industries, Spring 1989, v2 #1, pp 32-41.

Magnetocaloric Effect and Refrigerant Capacity of Tb-Dy Alloys

S.A. Nitkin, et.al, *Physics Status Solidi (East Germany)*, May 1989, pp 117-121.

Magnetic Refrigerator for Superconducting Magnets at 1.8K

V.A. Altov, et.al., *ICEC 12 (UK)*, 1988, pp 635-640.

Magneto-thermal Properties of Sintered Gadolinium

E. Gmelin, et. al., *ICEC 12 (UK)*, 1988, pp 432-436.

Determination of the Cooling Capacity of Magnetic Refrigerants

S. Nikitin, et. al., *Soviet Technical Physics Letters*, April 1988, v14 #4, pp 327-328.

Magnetic Refrigerator

T. Hashimoto, *Refrigeration (Japan)*, 1988, v63 #733, pp 1189-1201.

Magnetic Field Changes in the Entropy of Europium Sulphide

P. Bredy, et.al, *Cyrogenic (UK)*, Sept 88, v28 #9, pp 605-606.

Magnetothermal Conductivity of Er-Al for Cryogenic Applications

C.B. Zimm, et.al., *Journal of Applied Physics*, 15 April 1985, v57 #8, p4294-4296.

Adiabatic Temperature Changes in Ferromagnetic Intermetallic Compounds

C.B. Zimm, et.al., *Journal of Applied Physics*, 15 April 1985, v57 #8, p3829.

Magnetic Refrigeration

T. Hashimoto, et. al., *Solid State Physics (Japan)*, March 1985, v20 #3, p161-175.

Characteristics of Magnetocaloric Refrigerants below 20K

T. Hashimoto, et.al., *ICEC 9 (Japan)*, May 1989, pp 26-29.

A Composite Material for Magnetic Refrigeration Using Internal Heat Transfer.

B. Daudin, et.al, *Cyrogenics (Great Britian)*, September 1982, v22 #9, pp 439-440.

Magnetic Refrigeration from 10K to Room Temperature

T. Hashimoto, et.al., *Cyrogenics (Great Britian)*, November 1981, v21 #11, pp 647-653.

T-S Diagram for Gadolinium Near the Curie Temperature

S. Benford, et.al., *Journal of Applied Physics*, March 1981, v52 #3, pp 2110-2112.

The Magnetocaloric Effect in Dysprosium

S. Benford, et.al, *Journal of Applied Physics*, March 1979, v50 #3, pp 1868-1870.

Fig. 4 – A FEW OF THE RECENT PAPERS on magnetic refrigeration and the new magnetocaloric effect.

the virtually unknown *Science Citations Index*. Unlike all the others, this one lets you move *forward* through time, rather than back into older and older material. This works by listing who put whom into their end-of-paper bibliographies.

For instance, any competent new technical paper on active filters *must* reference *Sallen and Key*. Anything new on cold fusion absolutely *must* list *Pohns and Fleishman*. Anything new on unfocused solar collectors simply *must* cite *Winston*, and so on. If they don't, then they aren't worth reading anyhow.

Simply shove any of these names through the index, and you generate all of the newer papers in the field. After a while, new author names will start cropping up and repeating. You then use the *avalanche effect* to find the latest and the best, just by starting with one or two ancient authors.

And do not ignore the library's kiddie, young adult, or popular press books. Excellent, understandable and readable backgrounds can be easily picked up in the *Doubleday Science Series*, or the *Life Science Library*.

Beyond the library, you'll want to collect the specialty direct mail books catalogs. We've covered this resource in depth in a previous column and contest. More details in my *Hardware Hacker II* reprints.

Let's see. What else can you do?

You'll definitely want to set up some sort of an extensive personal network that involves people strictly *outside* of friends, family, or work associates. Obviously, my help line works like a champ here. Electronic bulletin board systems are another great route to networking. So are clubs.

Your own personal experiments can very much clarify any topic, as can teaching a class about it. The purpose of research is to get the effect you are after to show up reasonably well in as simple and as cheap a way as possible.

But stay in school forever. While there's lots of possibilities here, the best I've found are local community college courses, and that self-study material from *Heath*.

Finally, simply let things gel. Take Bowseretta up the mountain. Quest a tinaja. Map that terminal crawlway. Any field has an order and a flow to it. Often in directions which "they" don't care to admit. Start with a few fundamentals, think about it for a while, and a pretty fair picture of the rest may fall in place without much in the way of conscious intervention.

Remember that sincerity is everything. Once you've got that faked, all else follows.

This Month's Contest

Tellyawhat. I am about to reveal here for the first time a stunning new

technological breakthrough, one that is eminently hackable, besides being a sure fire winner for a research topic, school paper, or science fair entry.

Only instead of me doing all the work, let's try doing it together. See how much you can improve your research skills along the way.

Just show me an easily done and **Radio-Electronics** compatible method to demo the magnetocaloric effect described below, at room or lower temperatures. Or else add in any way (patents, papers, articles, data sheets, etc...) to our ongoing magnetic refrigeration dialog below.

There'll be all the usual *Incredible Secret Money Machine* book prizes, along with an all expense paid (FOB Thatcher, AZ) *tinaja quest* going to the very best of all. As usual, send your written entries directly to me here at *Synergetics*, rather than on over to **Radio-Electronics** editorial.

Magnetic Refrigeration

There's apparently a brand new way to cool things that is just turning the corner from laboratory work to preliminary product development. If what has happened so far is to be believed, it should completely blow away many of the traditional cooling schemes, particularly for very low temperatures.

This genuine new breakthrough is called the *magnetocaloric effect*, and I have grossly oversimplified it in my figure three. The latest key papers appear in the listings of figure four.

Basically, if you take critical rare earth elements or their alloys, they will absorb heat when magnetized and release heat otherwise, acting as a heat pump. At least over some temperature ranges and over specified magnetic field strengths. Gadolinium is one popular material.

Heat transfer operations take place in and around the *Curie Point*. Most magnetic materials lose many of their properties should they exceed their Curie Point temperature.

The magnetocaloric effect can be tuned over a range of absolute zero to above room temperature. Efficiencies which are as much as 40:1 better than mechanical refrigeration have been bandied about. Yes, the effect can be done using no moving parts.

Obvious applications for magnetic

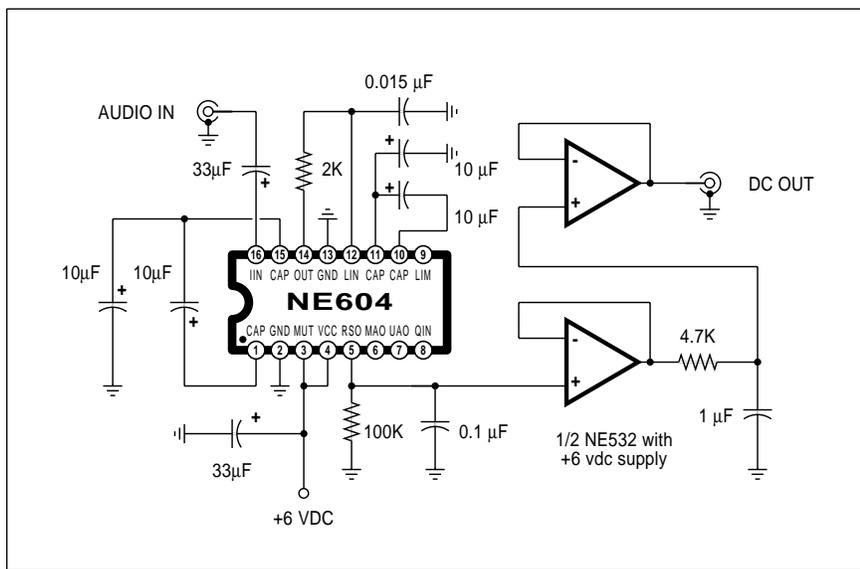


Fig. 5 – AN AUDIO VOLTMETER having an range of 0 to -80 DBM. Use this one to calibrate microphones and speakers, or as a receiver "S" meter. Output is 0.5 volts at -80 DMB and 5 volts at 0 DBM. Sensitivity is 10 microvolts.

refrigeration include cryogenics and superconductivity, the production of liquid gases (especially hydrogen as a fuel), and as Freon replacements for traditional room air conditioners. A few sources for gadolinium and its related rare earths are shown in our *Rare Earth Resources* sidebar.

This is all so new and so hot (Uh—better make that so *cold*) that I don't have too much for you beyond these key papers of figure four. One very detailed and thorough but extremely expensive report on this magnetic refrigeration is now available through *Technical Insights*. Much more on all this when I actually get the papers and can do some hacking of my own.

UPDATE: More info on magnetic refrigeration does appear in *Hardware Hacker* #35.

An Audio Voltmeter

Signetics has an intriguing cellular radio log amplifier chip in their NE604 and described in their new ap-note AN-1991. Figure five shows you how to use this chip to build an audio level meter usable over an incredible 0 to -80 DBM range. It accepts audio levels as low as ten microvolts, and should be useful for speaker and microphone testing, as well as for a receiver "S" meter.

Reasonably priced and wide range log amps are a rarity, so this is a welcome chip. Be sure to let me know what other uses you can come up with for this gem.

New Tech Literature

Three free new data books from *SGS* do include their *Power Bipolar Transistors, Zener and Rectifier Diodes*, and their new 1990 Shortform Catalog. From *Micron*, a *MOS Data Book* mainly on static and dynamic memories. From *Micro Linear*, a *1990 Data Book* featuring A/D, D/A, telecomm, and power supply circuits. And, speaking of telecomm, be sure to get the new *Telecommunications Data Book* from *National*.

Two hacker surplus sources with very low prices include *Short Circuits* and the *Electronic Goldmine*.

Automotive Electronics is a very interesting new trade journal, while *Electronic Components and Applications* is an outstanding quarterly tech journal from *Philips*. The cost is a tad

RARE EARTH RESOURCES

Aesar

Box 8247 Ward Hill
Haverhill, MA 01835
(800) 343-1990

Alfa Products

PO Box 8247
Ward Hill, MA 01835
(800) 343-0660

Cerac

PO Box 1178
Milwaukee, WI 53201
(414) 289-9800

ESPI

5310 Derry
Agoura, CA 91301
(800) 638-2581

Fisher Scientific

711 Forbes Avenue
Pittsburgh, PA 15219
(412) 562-8300

Goodfellow

301 Lindenwood Drive Suite 1
Malvern, PA 19355
(800) 821-2870

high at \$20 per year for what should be a free house organ. The latest issue includes info on solid state visible laser diodes, pagers, phaselock loop circuits, and oscilloscope tubes.

The bargain of the month has to be *Jerryco's* stock #79106 copy machine chassis. This is a wide dual-bin input feeder and registration assembly for \$10.50. As is, its a great electromechanical treasure trove. With some stupendous hacking effort, you might convert this into a fake Kroy Kolor machine, an automatic dual bin laser feeder, or find some unique robotics applications for it.

Arlyn Shepard of *Lazer Products* tells me he has at long last found a few more *Canon* fusing units. We looked at these several columns ago for Kroy Kolor, lamination, and for dry film printed circuit bonding.

Arlyn is also my favorite source of recharging supplies. He offers toners, wiper pads, seals, pixie dust, and lots more. As we've seen in the past, you can reduce your laser printer toner costs by 20:1 or more by doing your own cartridge refilling.

Adobe Systems has released their new black book, otherwise known as the *Adobe Type 1 Font Format*. This has all of the previously secret insider stuff on their encrypting, compacting, and the hinting of high quality typography. I do have a few copies on hand here if you need one.

Our free mechanical samples this month include *Alumilite*, an easily castable urethane that sets in three minutes. It easily holds small details. And the *Cycle-Flex* mechanical drive cables and fittings from *CMA*.

Rounding out the free samples for

today are those *Bend-Flex* flexible printed circuits from *Rogers* and the *Conpad* elastomeric battery clip replacements from *Stockwell*.

A *High Current Transistor Design Guide* wall chart is available through *PowerTech*. And *Rochester Electronics* offers a new inventory guide to discontinued semiconductors.

Tec Spec is an outstanding hacker newsletter chock full of easy to build and hands-on stuff, including Van De Graff generators, visible lasers, and do-it-yourself vacuum pumps. A free sample copy is available.

UPDATE: Sadly, *Tec-Spec* ceased publication in August of 1992.

Another special interest newsletter is the ongoing *Tesla Coil Builder's Association* quarterly. This one is \$20 per year.

Turning to my own products, I do have complete autographed sets of all of my book-on-demand published *Hardware Hacker II* reprints for all my **Radio-Electronics** columns here waiting just for you. And, for more information on self-directed research, be sure to check into my *Incredible Secret Money Machine*.

Finally, I do have a new and free mailer for you which includes dozens of insider hardware hacking secret sources. Write or call for info.

Our usual reminder here that most of the items mentioned appear either in the *Names and Numbers* appendix or the *Rare Earth* sidebar.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8-5 in *Mountain Standard Time*. Let's hear from you. ♦

Don Lancaster's Hardware Hacker

October, 1990

Using SAW Devices
Designing Active Filter
Digital Signal Processing
Switched Capacitor Filters
Unique Digital Thermometer

Our no-charge RE Hardware Hacker helpline sure gets a lot of queries on filters and filtering. So, for this month, I figured we might go over several filter fundamentals, especially for deciding exactly what kind of filter should get used where...

Passive Filters

An electronic *filter* is some frequency selective network that favors certain frequencies at the expense of others. Filters are normally used to strengthen wanted signals while you try to reject unwanted ones.

Traditionally, filters were built by using combinations of inductors and capacitors. These are called *passive filters*, and three examples appear in figure one.

In 1-A, we have an example of a *low pass* filter. At lower frequencies that inductor appears as a piece of straight wire and the capacitor's reactance is extremely high. So dc and lower audio frequencies are readily passed. At very high frequencies, the inductor looks like a high blocking impedance and the capacitor looks like a very low shunting impedance, so all the high frequencies will get strongly attenuated.

The one-two punch of this example makes this a *second order* filter. At low frequencies, the response is flat. At high frequencies, the response will quarter with each doubling of your frequency, falling off at a -12 decibel per octave rate.

Just what will happen at the *corner frequency* with this circuit? That all should depend upon your *ratio* of the inductance to capacitance. Should you seek out the smoothest possible response, you can adjust the ratio of L to C so that your response ends up precisely 3 decibels down, or roughly 70 percent of the amplitude at the corner frequency. This -3 decibel point could also be called the *cutoff frequency*. Such a low pass filter with the smoothest possible passband is known as a *Butterworth* filter.

The L/C ratio of this circuit is also

known as the *damping*. If you end up *critically damped*, you should get the smoothest possible response. If you are *underdamped*, you get a rising or a peaked response at your corner frequency. If you are *overdamped*, you get a very droopy result.

A simple *treble* control on a hi-fi is an example of a low pass filter.

A *bandpass* filter appears in figure 1-B. At rather low frequencies, your capacitor provides a high reactance, and your response *increases* at a +6 decibel/octave rate. At the resonance, otherwise called the *center frequency*, both the reactances cancel, giving you unity gain. At the higher frequencies, the inductor provides a high series reactance, and the response *decreases* at -6 decibels per octave.

The ratio of the inductance to the capacitance sets the damping, which in turn will set the sharpness of your resonant peak. Since very low damping values are most often involved, a factor known as the Q is used instead. This Q, or "quality" factor ends up as the inverse of the damping. The Q is also the bandwidth of the center peak between its -3 decibel points.

Note that, no matter how high the Q, the slopes at very low and very high frequencies will stay at +6 and -6 decibels per octave. Your choice of Q only determines the narrowness

and the peakedness of the response *at or near resonance*.

The tuning dial on an AM radio is an example of a bandpass filter.

A second order *high pass* filter is shown in figure 1-C. Here, the high impedance of the series capacitor and the small impedance of the shunting inductor attenuates the very low frequencies, creating a double whammy attenuation rate of +12 decibels per octave. At higher frequencies, the capacitor's reactance is low and the inductor's is high, freely passing the highs without attenuation.

At the corner frequency, you will once again get a peaked, smooth, or drooping response depending on your L/C ratio and its damping factor.

The *bass* control on a hi-fi is one example of a high pass filter.

Actually, there is no such thing as a true electronic highpass filter, since one of these would also have to pass microwaves, heat, light, and X-rays. At very high frequencies, the circuit strays (such as a capacitor self resonating on its own leads) can alter the high end performance.

High pass filters also do tend to be "noisy", since they freely pass all the harmonics of all supposedly rejected waveforms. Compared to a low pass filter, which carries out one or more integrations, a high pass filter does

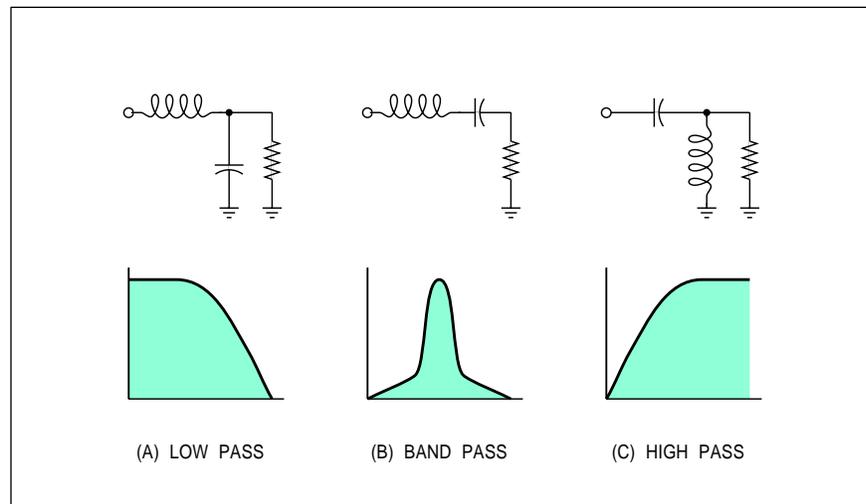


Fig. 1 – THREE EXAMPLES of second order passive LC filter sections.

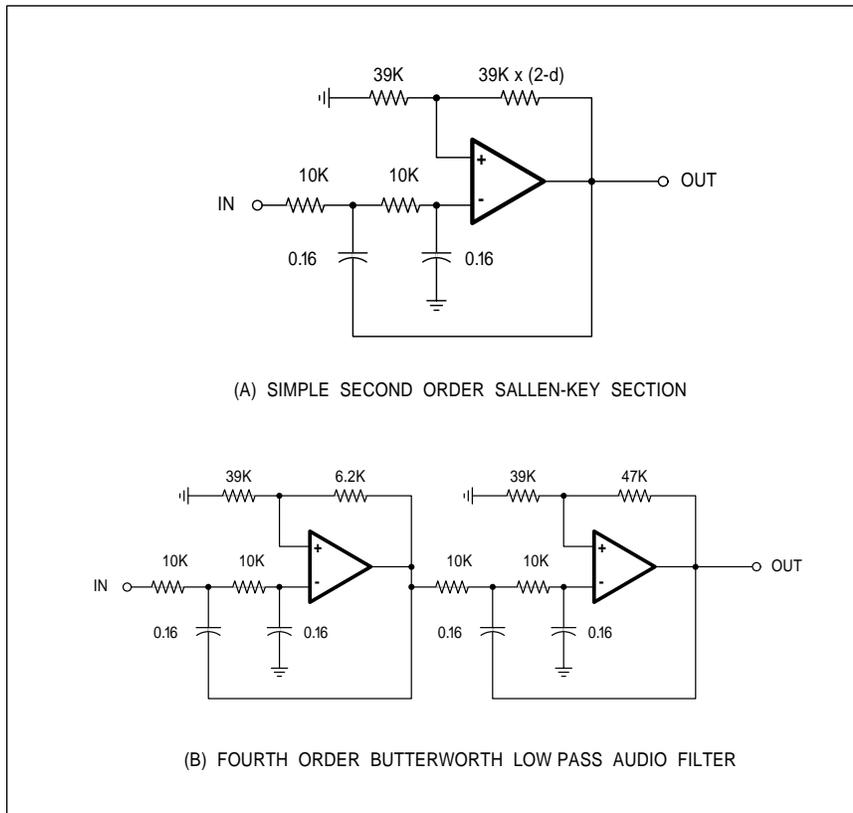


Fig. 2 – TWO SALLEN-KEY LOW PASS active filters. Most any premium grade of op-amp can be used. Components should be 5% or better.

one of more differentiations, or slope extractions. This also can add to your overall noise.

Fancier filter responses are picked up by using additional inductors and extra capacitors to increase the *order* of your filter. Unfortunately, you can not just "stack up" passive sections. Each in turn has to play a specific and very often a non-obvious part in your overall desired response.

My favorite passive filter book is Weinberg's ancient *Network Analysis and Synthesis* (McGraw Hill, 1962). The *Radio Amateur's Handbook* also has loads of good passive filter design info in it, as do most college level circuit or network texts.

These days, you'll usually try to avoid passive filters like the plague, since they are bulky, expensive, and hard to redesign, calibrate, or adjust.

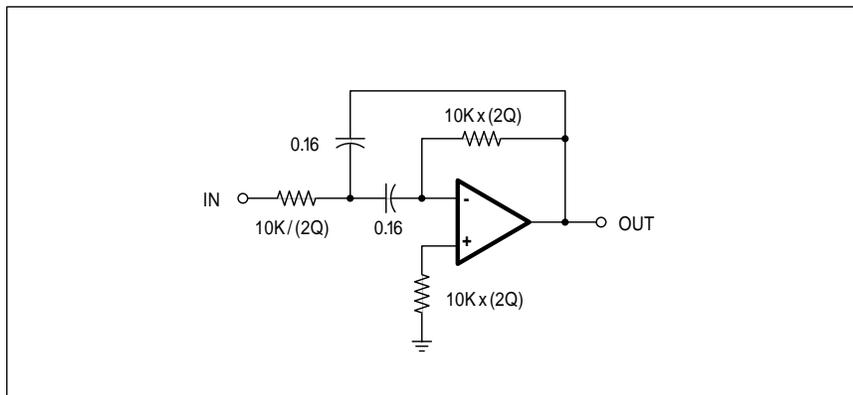


Fig. 3 – THIS SINGLE AMPLIFIER MULTIPLE FEEDBACK bandpass active filter can only be used for Q values of ten or less.

They also lack gain and do require carefully controlled source and load impedances. So, you'll want to avoid passive filters at all costs.

Unless you happen to be working with extremely low signals, at some rather high power levels, or at very high frequencies where nothing else will do the job.

The usual way of filtering stuff today involves...

Active Filters

With an *active filter*, you can use combinations of resistors, capacitors, and operational amplifiers to fake the response you'd get from a passive LC filter. Some energy from your power supply is used to substitute for the energy normally stored in an inductor's magnetic field.

Important advantages of the active filters are that there are no inductors involved, they are easy to design, and they are easy to tune.

Because the active filters can also provide buffering and gain, they are far less sensitive to source or load impedances than passive filters.

While there have been many different active filter design methods in the past, only two have survived and remain popular today. These are the everyday *Sallen-Key* single op-amp filters and higher performance *State Variable* filters which need three or four op-amps for each of their second order sections.

Figure 2-A shows you the second order Sallen-Key low pass filter, normalized to a 10K impedance level and a 1 kHz cutoff frequency.

The original horse's mouth on this was A. Sallen and Key's *A practical method of designing RC active filters* from the *IRE Transactions on Circuit Theory*, March 1955, pp 74-85.

Their prototype Sallen-Key filters were intended for use with cathode followers, the vacuum tube precursor to a transistor emitter follower. These were designed to work with a unity or slightly lower gain. Which forced you to select weird ratios for capacitors and caused an interaction between the corner frequency and your desired damping.

Many years ago, I played around with the Sallen-Key math in detail and came up with a twist that made these filters far simpler to design and

actually use. I named this the *Equal Component Value* Sallen-Key filter. In figure 2-A, both capacitors are of identical size and set only frequency. And both resistors are also identical size and also set only the frequency. The op-amp gain independently sets the damping to a chosen value.

To scale your frequency, you just *increase* either resistor pair or either capacitor pair to *lower* frequency, and vice versa. To scale the impedance, proportionately raise the resistors and lower your capacitors. Full details in my *Active Filter Cookbook*.

Usually, you combine, or *cascade* second order sections to build up any fancier filter of higher order. By very carefully selecting the damping value and corner frequency of each second order section, you could produce an overall filter response of most any desired complexity.

Some of these fancier responses do have specific names. For instance, a *Bessel* filter will give you the flattest possible time delay at the expense of the amplitude falloff. As we've just seen, a *Butterworth* filter could give you the smoothest possible amplitude response. If you are willing to allow some lumps in the passband, you end up with a *Chebyshev* filter. Popular Chebyshev filters can get built up with one, two, or even three decibels of passband ripple. Finally, the *Cauer* or *Elliptical* type filter will also add "zeros" to your stopband, giving you the fastest possible falloff just outside the passband.

One thing which many beginning hackers miss: If your filter is made up of cascaded and isolated second order sections, *the only difference between all of these filter types lies in how you select your damping and the corner frequency of each section*. That's all. Thus, once you have a filter built, all you need do is change the damping and the corner frequency for each section to get any desired result from Bessel on through Chebyshev.

As with passive filters, you do not simply pile up identical second order sections. Instead, you must carefully select your damping and corner frequency of each section to properly interact with the others to get the final desired response.

Figure 2-B shows a fourth order Butterworth low pass filter having a 1

kHz cutoff frequency with a -24 decibel per octave rolloff. Note that the two sections are *not* identical.

Note also that a dc return path to ground absolutely *must* be provided back through the input source for a low pass active filter to work.

It has been pretty much proven to everyone's satisfaction that you can *not* build up a high Q active bandpass filter using only a single op-amp. The impedance levels, interactions, and gain requirements all gang up on you as you raise the Q.

Figure three shows you the best of a sorry lot of single op-amp second order bandpass filters. This one gets called a *multiple feedback* circuit. It is only recommended for Q values of 10 or less. Thus, while useful for such tasks as an equalizer or a psychedelic lighting filter, it is strictly limited to lower Q uses.

The higher performance workhorse second order active filter is called a *State Variable Filter* and can be built using three or four op-amps as shown you in figure four. This one has three separate lowpass, bandpass, and highpass outputs, is very well behaved, and can work with very high Q or low damping values. A fourth op-amp can be added to the circuit shown to make the gain independent of the damping.

Finally, figure five shows you a Sallen-Key single op-amp highpass circuit. This one is just the lowpass circuit of figure two "insided out" to get the complementary response.

Active filters get restricted by the frequency response, the slew rate, the distortion and noise floor of the op amp used. They are best used at audio and lower video frequencies having signals which are neither very small nor excessively big. Quality op-amps for active filters are available from *Linear Technology*, *Burr-Brown Inc.*, *Analog Devices*, *Maxim*, *National* and *PMI*.

By one of those utterly astounding coincidences that seem to infest this column, I've written an *Active Filter Cookbook* that somehow has gotten up to its fifteenth printing. It does include everything you need to build all your own real-world active filters.

You could write or call me for an autographed copy or two.

Other Filter Types

Besides passive and active filters, there are several other major new methods of filtering electronic signals that are of more than passing hacker interest. These now include *switched capacitor filters*, *digital signal processing*, and *surface wave devices*.

A *switched capacitor* filter is just that. Some integrated circuit which contains a bunch of small capacitors that are switched on and off to sample an input signal. If your switching is just right, the charge on the capacitor will follow and reinforce the input signal. If it is wrong, your charge on the capacitor will average out to zero. By carefully arranging the network of

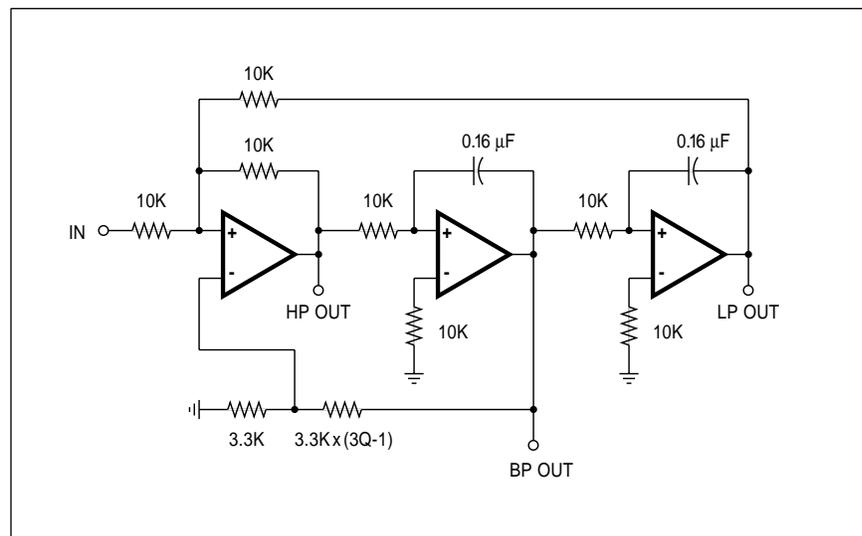


Fig. 4 – THIS STATE VARIABLE ACTIVE FILTER gives lowpass, bandpass, and highpass outputs and is best used for high Q or low d applications.

properly switched capacitors, you can favor selected frequencies and reject other ones.

The big advantages for switched capacitor filters are their electronic tunability and minimum cost. In the past, switched capacitor filters were noisy and often produced significant distortion. Today's circuits are better. They still do not handle extremely small input signals very well.

Important uses for these switched capacitor filters are modems, touch-tone detection, telecom in general, disk drives, CD players, industrial instrumentation, and data acquisition.

Several large suppliers of switched capacitor filters now include *Linear Technology*, *Maxim*, and *Exar*. All three sources have lots of data sheets and ap notes available.

A *digital signal processor* is just a specialized type of microcomputer. To do a filtering using digital signal processing, you first analog-to-digital (A/D) convert your input signal into strings of numbers in memory. Then you use digital techniques to modify those numbers in memory. Finally, you digital-to-analog (D/A) convert your filtered results.

While this may sound like a real runaround, these days you can digital signal process in one single and reasonably priced chip. There are many big advantages to DSP filtering. One big advantage is that you can easily create filters that can be extremely difficult or impossible to handle with passive or active analog techniques. Examples include "brickwall" filters having near-infinite response slopes, and filters with a constant phase or a

controlled group delay.

Another major advantage is a full programmability. Nothing changes except several software words if you want to completely change what your filter does or how it does it.

Most of those DSP chips are really specialized microprocessors. Usually they have powerful internal firmware commands which can let you rapidly multiply, shift, and add. They also usually provide specialized functions such as barrel shifting and zero time testing and branching. Fixed point and floating point processors are both available today.

DSP is obviously limited to lower frequencies unless you do not require real time results. You also have the usual aliasing problems and the A/D quantization noise limitations to cope with as well.

Important DSP chip uses include geophysics, biological research, for speech synthesis and recognition, radar, and electronic music. Just about all of the latest personal computers and synthesizers have gone the DSP route for most of their sound capabilities. The main manufacturers of DSP chips do include *Analog Devices*, *Texas Instruments*, *Motorola*, and *TRW*. All of these folks do have data books and detailed ap notes available.

Surface Acoustical Wave, or SAW filters are a specialized type of low cost filter which is quite popular in television and cable systems. These consist of a piezoelectric disk which has an acoustical transmitter and an acoustical receiver on it. Unlike your usual audio devices, these acoustical waves do involve sound waves whose

frequency typically lies in 40 to 400 Megahertz range.

Special finger-like contacts can be placed between the transmitter and receiver. These fingers cause constructive and destructive interference patterns that give the SAW device a specified response. Typical uses are for TV vestigial sideband filtering, for various descrambling circuits, and to set your IF amplifier passband in tv receivers.

The big advantages of SAW filters are that they are very cheap, accurate, stable and need no tuning.

Sadly, the SAW filters don't really hack all that well, even though you can readily find them for a buck each surplus. Any SAW filter handles one and only one specified job, done in a carefully specified manner at one specified frequency. And into one specified load from a specific source. They are not in any way tunable or adjustable. What you got is what you get. And your own custom SAW filter involves a very steep setup charge, comparable to that of a full custom integrated circuit.

One leading supplier for the SAW filters is *Plessey Signal Technologies*, while bunches of surplus sources do advertise in *Nuts and Volts*.

Let me know if you need any more details or use circuits for any of these alternate filter technologies.

This month's resource sidebar is on active filters and shows you many of the names and numbers you will need to get started.

A Digital Thermometer

Radio Shack now has a amazingly sophisticated digital thermometer that sells for less than twenty bucks. It is part number 277-123.

This beauty runs off a single AA battery and displays four digit LCD temperature in either Farenheit or Centigrade over a -40 to 122 F range.

Incredibly, there is a recording *max-min* feature and a settable alarm and controller capability. Both on-off levels and a 2 kHz piezo tone do get provided as outputs.

You have a choice of a one second or a fifteen second update for your display. Total operating current is in the microamp range.

Their out-of-the-box accuracy is only a degree or so Farenheit, but this

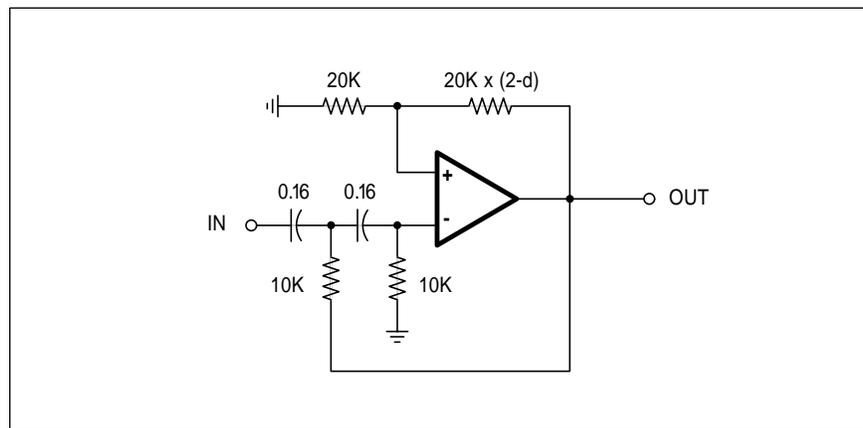


Fig. 5 – THE SALLEN-KEY HIGH PASS second order filter section is simply the lowpass circuit of figure 2-A insided out. Values are for 1 Kilohertz.

circuit seems stable enough that you just might custom calibrate it for such things as a hot tub controller or for cave stream temperature logging. The unit-to-unit variations are also within a degree. The resolution is a tenth of a degree and appears real. Although not waterproof, this gets easily fixed with a tube of silicon bathtub caulk.

As received, the device displays Centigrade at fifteen seconds per update. To select Farenheit with a one second update, just jumper pins 13, 14 and 16 on the edge connector.

We'll probably look at this gem in more detail in a future column. For now, let's make a contest out of it. We will have all the usual *Incredible Secret Money Machine* book prizes, along with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.

Either (A) show me a new and unusual application for a miniature and micropowered max-min thermometer; or else (B) show to me some simple and clean way to get all of the digital data out of the 277-123 into a remote computer.

As usual, be sure to send your written entries directly to me, and *not* to **Radio-Electronics** editorial.

New Tech Literature

New data books this month include the *Microcontroller Handbook* from Siemens, a new *Optoelectronics Data Book* from Sharp, an *OpAmp Macro-model Data Manual and Disk* from Texas Instruments, and that *Semiconductor Data Book and Ap Notes* from Unitrode.

From *International Rectifier*, a *Microelectronic Relay Design Manual*, and an *IGBT* product catalog.

And one stupendously impressive *Selection Guide to Integrated Circuits* from *Telefunken* that is chock full of unusual tv and auto chips.

Inks that can let you plot patterns directly onto all your printed circuit boards are available through *Loch Ness*. They also have some low end multilayer prototyping systems you may find of interest.

Testing surface mount devices and other weird or tiny packages can be a real hacker challenge. So, *Emulation Technology* has all sorts of adaptors and accessories that ease interfacing. Ask for their current catalog.

ACTIVE FILTER RESOURCES

Analog Devices

One Technology Way
Norwood, MA 02062
(617) 329-4700

Burr-Brown

6730 South Tucson Blvd
Tucson, AZ 85706
(602) 746-1111

Exar

Box 49007
San Jose, CA 95161
(408) 732-7970

Linear Technology

1630 McCarthy Blvd
Milpitas, CA 95035
(408) 432-1900

Maxim

120 San Gabriel Drive
Sunnyvale, CA 94086
(408) 737-7600

Motorola

Box 20924
Phoenix, AZ 85036
(800) 521-6274

National

2900 Semiconductor Drive
Santa Clara, CA 95051
(408) 721-5000

Nuts & Volts

Box 1111
Placentia, CA 92670
(714) 632-7721

Plessey Signal Technology

9630 Ridgehaven Court
San Diego, CA 92123
(619) 571-7715

PMI

1500 Space Park Drive
Santa Clara, CA 95052
(408) 727-9222

Synergetics

Box 809
Thatcher, AZ 85552
(602) 428-4073

Teledyne Semiconductor

1300 Terra Bella Avenue
Mountain View, CA 94043
(415) 968-9241

Texas Instruments

PO Box 1443
Houston, TX 77001
(800) 232-3200

TRW

Box 2472
La Jolla, CA 92038
(619) 475-1000

An Overview of SCSI Concepts is a great new manual available free from *Peer Protocols*. Three off-the-wall odd magazines include *Extraordinary Science*, *Surplus News*, and *Science Frontiers*.

Free software demos this month include that H8SX calculator disk from *Hewlett-Packard*, and the 945 heater controller demo from *Watlow*.

A free mechanical sample of *GUR* is available from *Hoechst*. This is a new plastic which is tough, cheap, self-healing and slippery.

A pair of data books and a postcard samples order form from *Maxim* includes *Analog Product Highlights* and their *New Releases Data Book..* From *PMI*, a humongous *Analog Integrated Circuits Data Book #10*. Four pounds and several thousand pages. Included are all of the old SSM (Solid State Music) chips.

The latest flyer by *All Electronics* includes \$6.50 strip chart recorders and \$15 COSMAC microcomputer trainers. For those of you who came in late, the CDP1804 COSMAC archi-

ture gave totally new meaning to the term *bizarre*. A most wondrous beast for sure.

Turning to my own products, for the fundamentals of digital integrated circuits, check into either my *TTL Cookbook* or *CMOS Cookbook*. And for those of you interested in that PostScript language or in Book-on-Demand publishing, our ongoing RoundTable is doing fine on *Genie*. By the time you read this, over 1000 free downloads should be available.

Finally, I do have a new and free mailer for you which includes dozens of insider hardware hacking secret sources. Write or call for info.

Our usual reminder here that most of the items mentioned appear either in the *Names and Numbers* appendix or in the *Active Filters* sidebar.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8-5 in *Mountain Standard Time*.

Let's hear from you. ♦

Don Lancaster's Hardware Hacker

November, 1990

Using Vortex Coolers
Polyphase Generators
Walking Ring Counters
Magnetic Refrigeration
Electronic Trade Journals

Some of you hardware hackers seem to make a big deal out of getting one or two pieces of newer electronic parts. As a general rule, if a chip house has a stiff minimum order, they often will be rather generous with free evaluation samples. All you usually have to do is ask for them in a professional manner.

Other times, some other hacker will recognize a need and fill it for you. For instance, Mike Giamportone of his *Thumb Electronics* is stocking the LSI melody chips for you at \$1.50 each.

Many of the other great LSI hacker chips are available in small quantities from *Belco Electronics*.

My new PostScript BBS is already going great guns on *Genie*. Yes, all of the "lost" Guru columns are here, as is much of the *Midnight Engineering* stuff. You'll find my insider hacker secrets brochure available as library downloads #112 and #113. You can also reach me here for email and such as SYNERGETICS.

All this on *Genie's* PSRT, and short for the *PostScript Roundtable*. For local connect info, call *Genie* (voice) at (800) 638-9636.

While I was wandering around a few of those other RoundTables on *Genie*, I did find a great radio and electronics board up at M345. These folks are heavily into monitor and scanner listings, satellite stuff, unusual receiver circuit hacks, general communications, and bunches more. They have thousands of downloads available for you.

Let's start off with some unique circuits known as...

Walking Ring Counters

I have always been attracted to *elegant simplicity*, circuits or software that do more with less in some superb or unique manner. In these days of FASTER CPU'S! and MORE MEMORY!, any elegant simplicity seems to have fallen by the wayside.

For instance, the game paddle port on an Apple IIe runs a LaserWriter *twice* as fast as the Mac IIcx and *three times* as fast as any other Mac. Yet for

some strange reason, Apple does not appear to be shouting this fact from their Cupertino rooftops.

Since no good deed ever will go unpunished, elegant simplicity will *always* get ruthlessly stomped upon whenever and wherever it occurs in the real world.

One older and classic example of elegant simplicity is the *Walking Ring Counter*. This is a hardware circuit or a software routine which generates a unique count sequence in a simple, unusual, and quite sophisticated manner. When used in the right place at the right time, The walking Ring Counters can provide very clean solutions to electronic problems that otherwise are often sloppily or klutziy done.

Walking ring counters are also sometimes called *Johnson Counters*. To build a walking ring counter, take a string of type D flip flops or adjacent bits in a software word. Cascade the flip flops as an ordinary serial shift register, but connect the Q output of the last stage back to the D input of the first stage. Then you clock all of the flip flops from a common source.

Figure one shows you a three stage walking ring counter we'll be looking at shortly in more detail. For now, pretend this one is a *five stage* counter instead of being only three stages long. Further, assume we have reset the counter to its 00000 state.

As you clock a five stage walking

ring counter, the following sequence is generated...

```
00000
10000
11000
11100
11110
11111
01111
00111
00011
00001
00000 (repeats)
```

Since we repeat after ten counts, we apparently have built a *decade*, or divide-by-ten counter. In fact, it turns out that the count length of a walking ring counter is normally *twice* your number of stages in use. Thus, three D-flops give you a divide-by-six, four a divide-by-eight and so on.

This is a *synchronous* counter, since all stages are clocked simultaneously. There are none of the glitches that get produced by a ripple counter.

Note that there are no intermediate frequencies. You have your input frequency and an output square wave of frequency $input/2n$, where "n" is your number of stages. Which makes the walking ring counter ideal for very high frequency use, especially as UHF and VHF prescalers.

Another unique property is that *all of the counter states can be decoded using only a single two-input NAND*

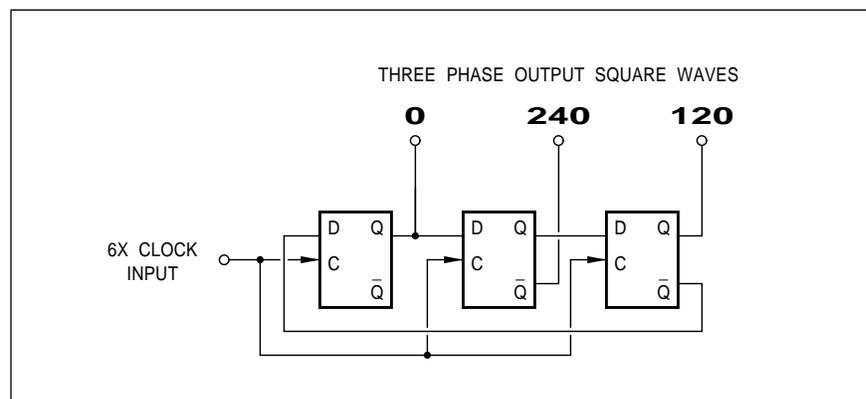


Fig. 1 – A THREE PHASE REFERENCE GENERATOR using a walking ring counter. The three output square waves produced are at one sixth the clock frequency and are precisely shifted by 120 and 240 degrees.

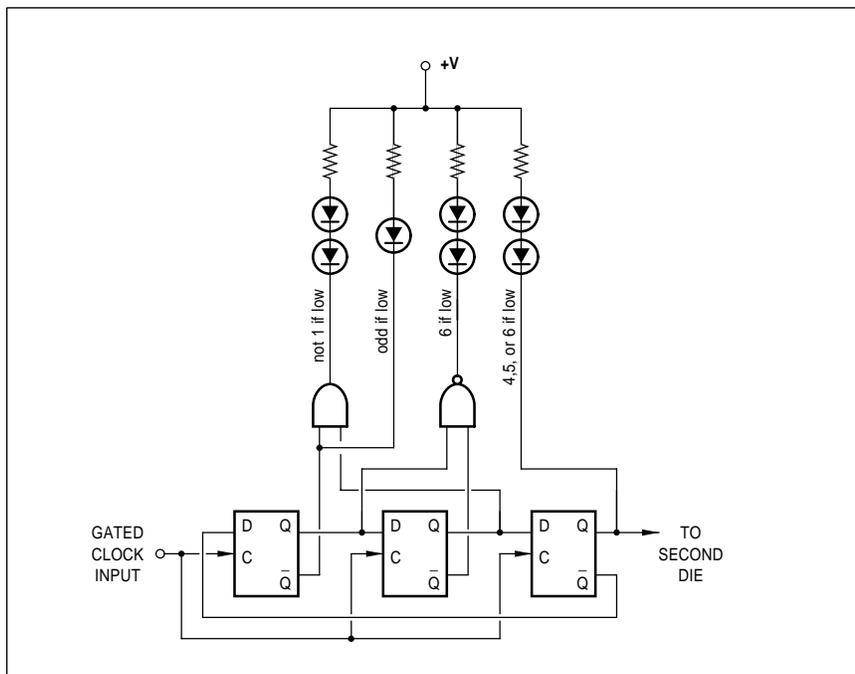


Fig. 2 – ELECTRONIC DIE uses a walking ring counter in an unusual 1-3-5-6-4-2 sequence to greatly simplify the spot decoding.

gate per state. Further, a full decode uses *all* of the Q and \bar{Q} outputs in a balanced and symmetrical manner. Back in the days when you worried about the *fanout* of a logic block, this was a really big deal.

I'll save the details on this for you to ponder over on your own, but most states decode using the Q output of one stage NANDed with the \bar{Q} output

of an adjacent one. Again in a very clean layout that is superb for high frequency use.

What is wrong with the walking ring counter? Elegantly simple or not, it does have two bad habits. The first is that you need half as many flip flops or word bits as your count modulo. Using five flip flops to divide by ten seems no big deal. But using 32 of them for a

divide-by-64 gets old in a hurry. Thus, walking ring counters are rarely used beyond a divide-by-twelve.

Any flip flop counter of any length can get into 2^n possible states. Thus, a five flip flop walking ring counter can get into 32 possible states, only ten of which are legal and allowed. If you inadvertently get into one of those "wrong" count states, you can get into a *disallowed sequence* that can cause you lots of grief.

As a ferinstance, the three stage, divide-by-six counter of figure one normally provides this sequence...

- 0 0 0
- 1 0 0
- 1 1 0
- 1 1 1
- 0 1 1
- 0 0 1
- 0 0 0 (repeats)

But if you ever get into the 0 1 0 sequence, here's what results...

- 0 1 0
- 1 0 1 (repeats)

All of a sudden you now have a divide-by-two counter instead of the divide-by-six. Which could really be bad news. Thus, *you somehow have to guarantee that a walking counter never gets into any disallowed states!*

Resetting the counter or else pre-loading your software registers are two good ways to prevent disallowed sequences. A sledgehammer cure is to always force internal 1 states whenever the two ends of the counter are also both set to 1. For instance, you could AND decode the outside Q outputs and use these to preset all the internal stages to their 1 state. This will quickly find any disallowed sequence and repair it on the fly.

Let's look at three uses for walking ring counters. I cannot believe how many really dumb circuits have been published in the trade journals that were intended to generate three phase power control signals.

As figure one shows us, all you really need is a divide-by-six walking ring counter. Provide six times your desired frequency, and you get three square waves out, all phase shifted by precisely 120 degrees.

You can obviously change the total number of stages for a quadrature output, for quad phase, five phase, etc.

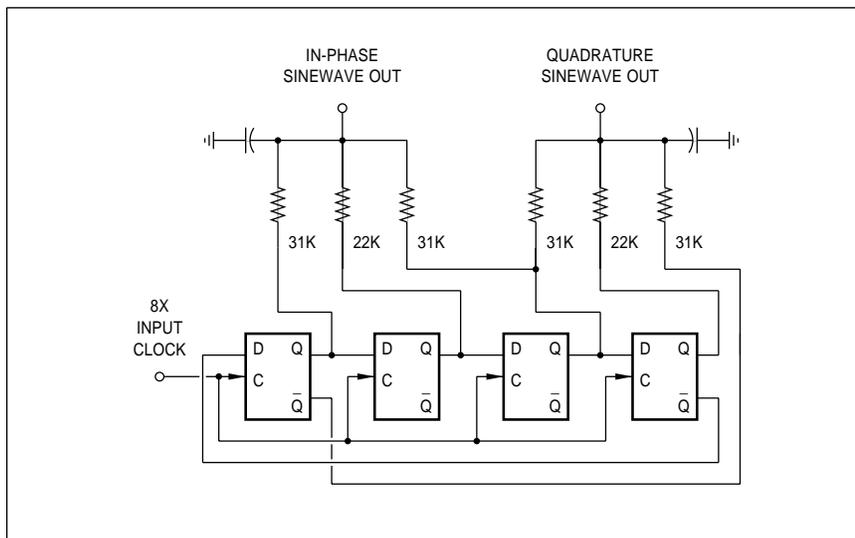


Fig. 3 – QUADRATURE SINEWAVES which are phase shifted by precisely 90 degrees are easily generated with a walking ring counter. The uses include single sideband communications and synchronous demodulation.

More details on all of this in my *CMOS Cookbook*.

Another great place to find lots of really klutzy circuits is in an electronic dice game. Figure two shows you the elegant simplicity of a walking ring die.

To understand this circuit, you first define your die spot count sequence as 1-3-5-6-4-2. This gives you a "free" even-odd decoding for the middle spot, and a "free" 4-5-6 decoding for two diagonal outside spots.

Use a NAND gate to decode "not 1" for the other two diagonal outside spots. Use an AND gate (or else two diodes) to decode "six" for those two outside middle spots. A medium frequency gated oscillator clocks the die, and a second die can be cascaded off the first one.

Finally, figure three shows you a digital sinewave generator that produces a pair of sinewaves frequency shifted precisely by 90 degrees. This circuit is based on stuff we looked at back in the January 89 RE. See my *Hardware Hacker II* for details.

I've purposely left the part numbers off all our figures this month, to encourage you to experiment on your own. Your best choices will be such chips as a 4013 or 74HC74 dual Type D flip flop. Most any parallel out shift register could also be used, as could software shift commands applied to any old alterable byte.

For our contest this month, either (1) Show me an unusual use for a walking ring counter, or else (2) show me some other circuit, tool, or technique that is elegantly simple.

There will be all of those usual *Incredible Secret Money Machine* book prizes for the dozen top entries, with an all expense paid (FOB Thatcher, AZ) *tinaja quest* going to the best.

More on Magnetic Refrigeration

The stuff is finally starting to pour in on *magnetic refrigeration*, our exciting breakthrough topic from two months back. Yes, this is all very legit and real. It is just being kept *very* quiet as all of the insiders scramble for real world product introductions. Insiders like Hughes, MIT, and Sandia Labs.

So far, very strong magnetic fields are involved and, while useful at room temperature, most of the research is aimed at reaching very low cryogenic

temperatures.

The best paper I've seen so far is the *Magnetocaloric Effects in Rare-earth Magnetic Materials*, authored by A.S. Andreev and crew in *Soviet Physics Usp* 32 (8), August 1989.

Since an all solid state cooler would involve switching extremely strong magnetic fields, the chances are that some motion will be involved in most of the practical magnetic coolers.

Figure four shows you a *shuttle* type cooler. Gadolinium is moved to an area free of a magnetic field where it picks up heat from the object to be cooled. It is then moved into a very strong magnetic field where it dumps energy to a suitable heat sink. This cycle is repeated at an optimum rate for the quantities of heat involved.

Rotary coolers and *Sterling Cycle* coolers have also been proposed. See the above paper for more details. And let me know any new resources you run across on this.

Vortex Coolers

This is another type of "gee whiz" type of cooler that is useful for cooling electronic enclosures and doing such specialized things as preventing any needle breakage in heavy duty sewing machines. A vortex cooler has zero moving parts. While it looks and feels

like a perpetual motion machine, it is quite real and rigorously obeys the laws of thermodynamics.

As figure five shows us, a vortex cooler is nothing but a very specially designed nozzle. The input is connected to a source of compressed air, as is commonly found in most production areas. There are two outlets. Hot air comes out the hot end and cold air comes out the cold end.

Leading manufacturers of vortex coolers are *Vortec* and *Exair*. They both have lots of catalogs, cassette tapes, data sheets, and application notes available.

How does it work? The air enters tangentially at faster than the speed of sound and forms a rapidly spinning hollow vortex cylinder having a very high angular velocity. When it gets to the hot end, some of it is released to ambient, and the rest of it spirals back *inside* the spinning hollow inlet air vortex cylinder.

Now for the tricky part. The inlet air and the outlet air are both spinning at the same radial velocity, since they are in contact with each other. But the *momentum* of the inside air has to be less since it has a smaller radius of rotation, and since angular momentum is inversely proportional to the spinning radius.

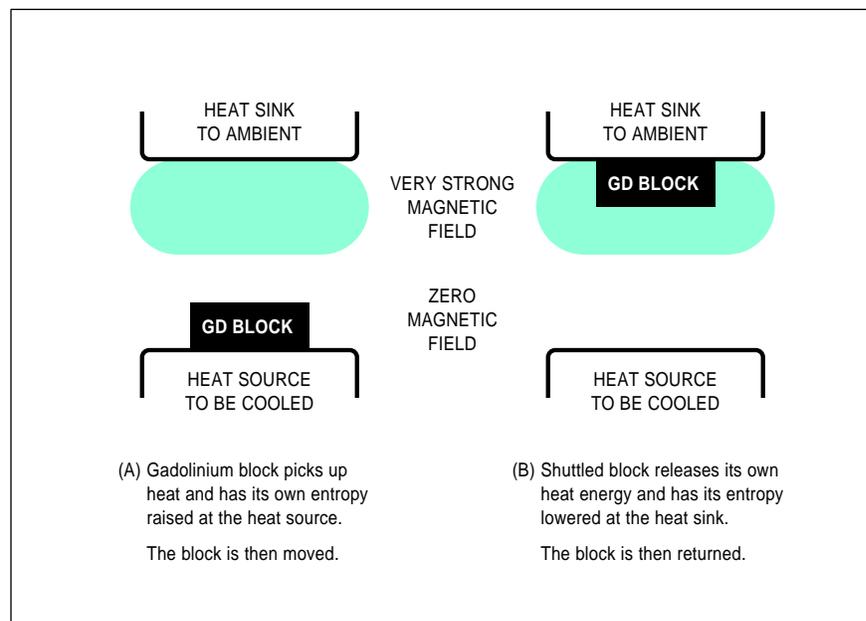


Fig. 4 – THE SHUTTLE TYPE MAGNETIC REFRIGERATOR moves a block of Gadolinium between a heat source in a magnetic field free area and a heat sink in a quite strong magnetic field area. This type of heat pumping can end up extremely efficient, especially at cryogenic temperatures.

ELECTRONIC TRADE JOURNAL RESOURCES

Appliance

1110 Jorie Blvd,
Oak Brook, IL 60522
(708) 990-3484

Circuit Design

1790 Hembree Road
Alpharetta, GA 30201
(404) 475-1818

Circuits Manufacturing

500 Howard Street
San Francisco, CA 94105
(415) 397-1881

Defense Electronics

6300 S. Syracuse Way,
Englewood, CO 80111
(303) 220-0600

Design News

275 Washington Street
Newton, MA 02158
(617) 964-3030

EDN

275 Washington Street
Newton, MA 02158
(617) 964-3030

EE Times

600 Community Drive
Manhassat, NY 11030
(516) 365-4600

Electronic Comp. News

One Chilton Way
Radnor, PA 19089
(215) 964-4345

Electronic Design

611 Route #46 West
Hasbrouck, NJ 07604
(201) 393-6060

Electronic News

7 East 12th Street
New York, NY 10003
(212) 741-4230

Electronic Pack & Prod

1350 East Touhy Avenue
Des Plaines, IL 60018
(708) 635-8800

Electronic Products

645 Stewart Avenue
Garden City, NY 11530
(516) 227-1300

Electronics

611 Route #46 West
Hasbrouck, NJ 07604
(201) 393-6060

Machine Design

1100 Superior Avenue
Cleveland, OH 44114
(216) 696-7000

Measurement & Control

2994 W. Liberty Avenue
Pittsburgh, PA 15216
(412) 343-9666

Motion

PO Box 6430
Orange, CA 92613
(714) 974-0200

PCIM

2472 Eastman Avenue
Ventura, CA 93003
(805) 658-0933

PCNetwork

30 Moran Street
Newton, NJ 07860
(201) 383-2296

air supply. And your air has to be extremely clean and extremely dry if the cooler is not going to freeze or jam. These can be noisy. And the pricing in single quantities often approaches \$100 for industrial units.

Question: Could you put a vortex cooler in a car vent? Let's have your thoughts on this.

Electronic Trade Journals

As we've seen a number of times in the past, there's simply no way you can be serious about hardware hacking if you do not aggressively subscribe to the industry trade journals. For our resource sidebar this month, I have gathered together a few of the more interesting and more important electronic magazines for you.

Most of these are free to "qualified" subscribers. You usually can qualify by using your PostScript business letterhead and your company name, and then telling them what they want to hear on their qualification card. The whole reason for their qualification process is so the mags can get a special *controlled circulation* postage rate. As long as you are genuinely interested in what their advertisers have to offer, you're wanted as a subscriber.

To find other magazines not on this list, you'll want to once again refer to the *Hacker's Holy Grail*, which is otherwise known as the *Uhlrichts Periodicals Directory* on the reference shelf of your local library.

Let's see. I guess the three "best" and most useful of these would be *E.E. Times*, *EDN*, and *Electronic Design*. But all of those others are certainly worth a look.

Once you get a subscription, you use the bingo cards, fax sheets, and mail coupons to pick up data books, samples, application notes, the whole bit. Many of the magazines also offer annual directories that can be most useful in pinning down an oddball part or an obscure source.

Lots more details on making your hardware hacking into a useful tech venture do appear in my *Incredible Secret Money Machine* book and in *Midnight Engineering*. If you have any favorite trade journals not already on this list, please let me know some more about them. As usual, names and numbers appear in the appendix or the above sidebar. ♦

Because the momentum must be preserved, energy is transferred from the inside spinning air cylinder to the outside one. This cools the cold end exit air as it heats the inlet air.

Full details appear in the *Vortec* application notes.

There is usually an adjustment screw that lets you vary the ratio of hot to cold exit air. One setting gives you

the lowest possible exit temperature, which routinely can go as low as -40 degrees. A different setting gives you the most efficiency and the maximum cooling at a higher exit temperature.

The air consumption and the overall efficiency are acceptable for most current uses.

What are the limitations to vortex cooling? Obviously, you do need an

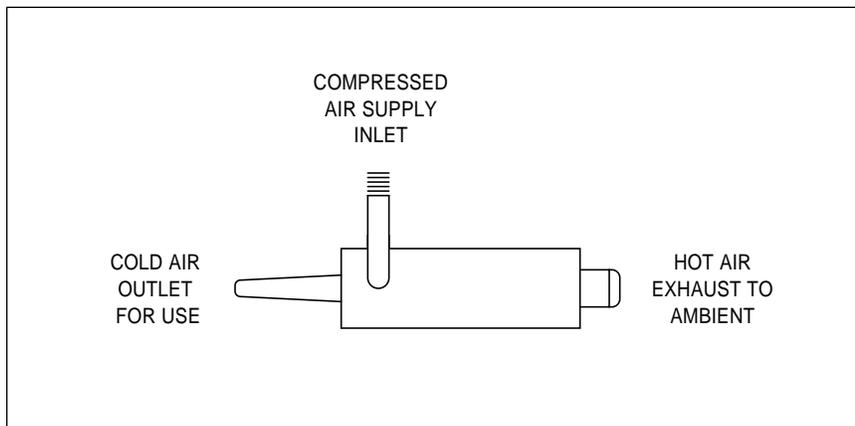


Fig. 5 – A VORTEX COOLER has no moving parts, yet easily can provide an air stream as cold as -40 degrees. The key secret is a pair of coaxial vortex streams. In order to preserve angular momentum, heat energy gets transferred from the cold output stream back to the input air stream.

Don Lancaster's Hardware Hacker

November, 1990

Discrete Cosine Transforms
Digital Sinewave Generator
More on Video Compression
Santa Claus Machine Update
Audiovisual Switcher Circuit

Did I really do that? Well, I will admit I thought I had made an error once, but it turned out I was mistaken. At any rate, most of the op-amps in my October 90 RE *Hardware Hacker* column on active filters seem to be upside down.

All opamps in *all* figures should have their (-) or inverting input on the *top* and the (+) or non-inverting input on the *bottom*. Figure three is correct; figures two, four, and five do need revised. All of the illustrations in my *Active Filter Cookbook* are correct.

Sorry about that. Since all of my technical illustrations are submitted as "shoot-and-go" camera ready PostScript, I did it all by myself.

As all of you long-term *Hardware Hackers* already know, all the artwork you see in this column gets done with the *AppleWriter* word processor with my Apple IIe. No scanners or artwork generation packages of any kind are used; everything gets done directly with "raw" PostScript. That includes all the schematics, pictorials, charts, text boxes, all printed circuit layouts, and all of the perspective and isometric stuff.

Our superb new PostScript PSRT RoundTable (M835) is going great guns on *GENie*, and you'll also find some advance *Hardware Hacker* and *Midnight Engineering* info there for your downloading. You could also contact me there via email by using my [SYNERGETICS] address.

You can give *GENie* a voice call at (800) 638-9636 for connect info. They recently have reduced their rates and have expanded their many services. Nearly 100,000 library downloads are now available in one of the finest and highest quality shareware and public domain collections in the world. Just about all computers do get supported, major or minor.

My thanks to all of you perpetual motion builders for your thoughtful suggestions on how to shield, time, or rearrange all the magnets to get my energy producing gyroscope (Sept. 90 RE) to run, rather than simply latching

up. And an extra special thanks to the few of you that sent me all of those super-strong magnets to try.

There's lots of goodies this month. Let's start off with a...

Santa Claus Machine Update

The Science Fiction authors called them *Santa Claus* machines. Instant replication devices that, on command, could reproduce just about anything from a machine part to a computer to a new girlfriend to a roast beef on rye sandwich.

Today, this emerging industry goes by the names of *Desktop Prototyping* or *Instant Modeling*. So far, all these machines are limited to producing quite costly and somewhat crude solid models in a rather limited range of materials. And you'll still notice a

rather acrylic aftertaste to your roast beef sandwich.

But the hacking opportunities here do boggle the mind. Firstoff, today's machines seem obscenely overpriced. Second, the best possible prototyping method clearly does not exist in any of the crude approaches in use today. Third, and finally, there are all sorts of service bureau, rental, and franchise opportunities emerging.

There is no reason whatsoever why any hacker \$200 solution to desktop prototyping should not exist. And, needless to say, all the folks here at **Radio-Electronics** editorial will pay very well for a hacker friendly one.

The reasons to be desktop prototyping are obvious. Just like you can now instantly produce a *Book-on-Demand* home published volume, you

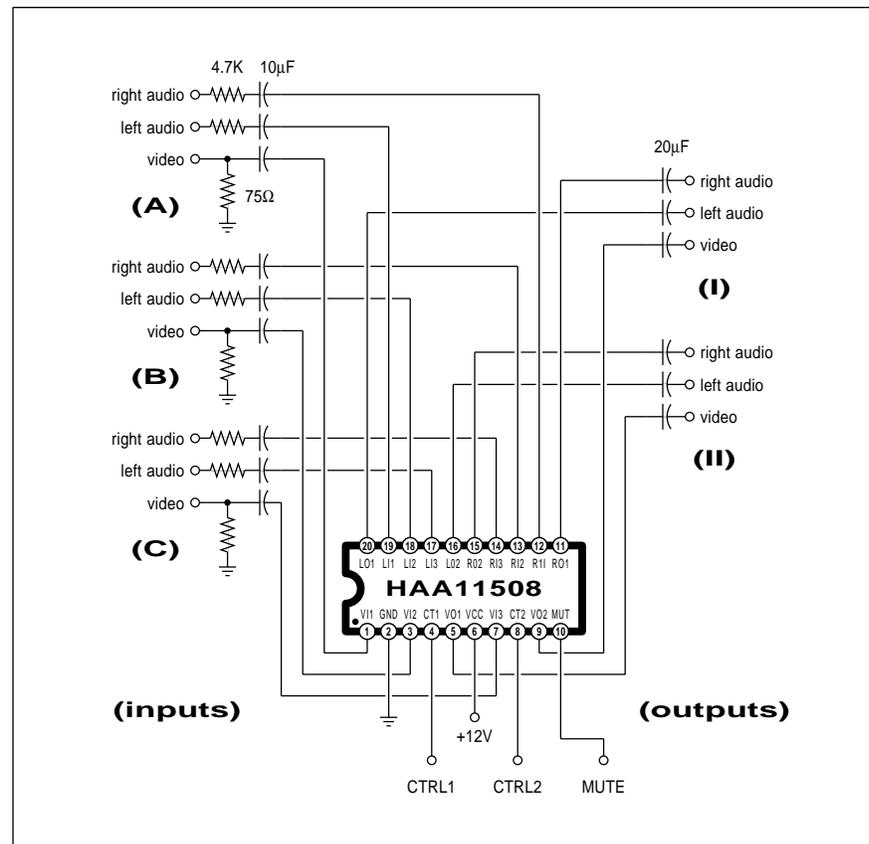


Fig. 1 – THIS TRIPLE AUDIOVISUAL SWITCHER uses the Hitachi HAA11508 to simultaneously select video and two channel stereo audio from any one of three sources and then route them to one of two selected outputs.

CTRL1	CTRL2	OUT I	OUT II
0	0	A	A
0	1	A	C
1	1	B	B
1	0	B	C

Fig. 2 – THE TRUTH TABLE for the triple audio switcher. Logic signals on the control inputs decide which input gets selected. An optional MUTE input turns off the audio only on output II.

should eventually be able to create virtually any object on a desktop. At pretty much the same cost and speed. All at development expenses and a time-to-market that are only a tiny fraction of traditional machine shop approaches.

And you should even be able to fake teleportation, simply by sending the replication codes to a remote machine over a satellite, modem, or fax line. Or, someday, a *Playmate of the month* on CD ROM. Yes, the real thing. No holograms need apply.

Our *Santa Claus Machine* resource sidebar for this month can show you where to go for more information on this exciting new field.

There are several dozen approaches to desktop prototyping, but those with the most commercial success so far are

limited to *lower end CAD/CAM, ultra-violet stereolithography, visible light stereolithography, and laser sintering*. Let's look at each in turn...

The low end CAD/CAM can involve miniature computer controlled milling machines or lathes, and the parts are produced in the usual way by using a cutting program. Today, most of these machines are aimed at the educational market. Sources include *masterCAM, Roland Digital, and Light Machines*, while others do advertise in *Industrial Education and School Shop*.

One material often used is a special *machinable wax* now available from *Freeman Supply*. This product is low cost, does not wear your tools, and can be recycled.

The pioneer in ultraviolet stereolithography is *3-D Systems*. The 3-D

system uses a tank of an uv-sensitive photopolymer. An elevator sits in the tank and is initially just below the surface. Their ultraviolet laser will selectively harden the photopolymer, hardening it out onto the elevator. Then the elevator gets lowered a few mils and the process repeated.

Pancake style, a composite object gets built up on a layer-by-layer basis. Compound curves and tricky undercuts that can be impossible to do the old way are easily done.

While the uv photopolymer used is normally both expensive and hard to get, a possible hacker substitute could be the *Merigraph* photopolymer used for rubber stamps, and available by way of *Grantham or R. A. Stewart*.

A second generation *visible light* photopolymer is getting developed at *Dupont*, and one major system which uses these is *Quadrax*. Advantages of the visible photopolymer include its lower viscosity, the ability to use a cheaper laser, and (with proper safety precautions) being able to see what you are doing.

Because of the lower viscosity, you can also *raise* the liquid level, rather than actually moving what you have already produced.

While these liquid vat methods do work, they are limited in accuracy to several mils, are rather costly, and end up severely restricting your choice of materials.

A fresh, different and totally dry approach to desktop prototyping gets used by *DTM*. Here a granular powder of certain waxes or any of a number of plastics is selectively hardened by an infrared laser in a process known as *sintering*. Sintering simply melts the surface of the granules so they stick together.

In addition to being cleaner and simpler, you have a wide variety of possible material options, including real metals. Many powders can be reground and recycled, and they are far cheaper than the photopolymers.

Let's see. A few loose ends. Other approaches to Santa Claus Machines include photochemical machining of thin layers and various other "gasket" techniques that get bonded together to produce composite objects. One think tank doing active instant prototype development is *Batelle*, while conventions and seminars are sometimes

A Fast Algorithm for the Discrete Cosine Transform
C.H. Smith, *IEEE Transactions on Communications* Sept. 1987 pp 1004-1009.

Image Compression for High Speed Network Transmission
C. Ciracia, *Circuit Cellar Ink*, Aug/Sep 1990, pp 19-26.

Teleconferencing
K. Rao, *Van Nostrand Reinhold Company*, 1985.

Digital Coding of Waveforms
N. Jayant, *Prentice Hall*, 1984.

A New Wave in Applied Mathematics
B. Cipra, *Science* 24 Aug 1990, pp 858-859.

Survey of Adaptive Image Coding Techniques
A. Habbibi, *IEEE Transactions on Communications*, Nov 1977, pp 1275-1284.

Advances in Picture Coding
H. Mussmann, *Proceedings of the IEEE*, April 1985, pp 523-548.

Progressive Transmission of Gray-Scale and Binary Pictures
K. Knowlnton, *Proceedings of the IEEE*, July 1980, pp 885-896.

Predictive Coding Based on Efficient Motion Estimation
R. Srinivasan, *IEEE Conf. Communications*, May 14 1984, pp 521-526.

DCT Processing of NTSC Composite Video Signals
A. Ploysongsang, *IEEE Trans. on Communications*, March 1982, pp 462-479.

Fig. 3 – A FEW OF THE RECENT PAPERS on video image compression and the DCT discrete cosine transform.

done by the *CAD/CIM Roundtable*.

One of many sources for traditional CAD/CAM support software appears to be *Control Automation*.

One thing that's totally obvious to me – the PostScript language will play a major role in the future of desktop prototyping. Obvious reasons here are PostScript's nearly total device independence, its incredible graphical performance (especially in all three dimensions), and its ability to let your favorite and el-cheapo word processor completely and totally blow away virtually *any* of today's costly CAD/CAM application packages.

For our contest this month, just add to our Santa Claus Machine dialog in some useful way. There will be all of the usual *Incredible Secret Money Machine* book prizes going to the dozen or so top entries, with an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.

As usual, please send your written entries to me here at *Synergetics*, instead of to **Radio-Electronics**.

An Incredible Data Book

Certainly one of the most beautiful, the largest, and the most impressive data books I've ever run across is the incredible new *ASSP for Audio and Video Applications* data book offered by *Hitachi*. And it is crammed to the rafters with unique new hacker integrated circuits.

Picking a sample more or less at random, our figure one shows you an *audiovisual* switch using their new HA11508 chip.

This beast is hard to describe. It *simultaneously* switches one video and two stereo audio channels from your choice of three sources. As figure two shows us, there are two separate triple outputs, selected per their *Control1* and *Control2* lines. The audio on the second triple output can be muted using the *Mute* input.

This dude is intended to select three audiovisual sources inside a tv set and route them out to two possible destinations. But it cries to be used as part of a home or low end studio audiovisual control center or a switching bay.

The quality specs seem fairly impressive. Although a 12 volt supply is recommended, anything from 8 to 13 volts can be used.

All the inputs and all outputs are supposed to get capacitor coupled. Since the switching times and all the overlaps are not specified, this chip appears mainly intended for use in static switching or source selection. Instead of being applied to chroma key or picture insertion applications.

Naturally, for any higher quality switching, full double sided pc boards and lots of ground plane are an absolute must.

More on Data Compression

There sure was plenty of ongoing hacker interest in all of that data compression stuff we looked at a few months back and in those *Hardware Hacker II* reprints.

Much of the action today centers on the new *Discrete Cosine Transform*, especially in higher resolution color computer and tv displays.

Figure three is a bibliography of some of the heavier duty papers on the DCT. Start out with Chris Ciarcia's introductory tutorial in *Circuit Cellar Ink*, and then go on to the fancier stuff by way of the *Interlibrary Loan* found at your local library.

To compress any video image, individual 8 x 8 pixel blocks have their discrete cosine transform taken, by using either using hardware or software. The result of this transform is a list of frequencies and amplitudes. Any change so minor that the eye can't see anyway gets replaced with a

zero, leaving a sparse data set.

Put another way, what you don't know (or see) won't hurt you.

The sparse data set then gets further compacted using *Huffman* or similar techniques. The net result is a video compression in the 30:1 range without significant visual degradation.

The reasons for compression is to reduce your disk storage time and your communication time. Far more importantly this sort of data compression is essential to squash a HDTV high definition video image on down into reasonable bandwidth channels. So knowing and understanding video compression is an essential part of the new multimedia revolution that is combining video and computing.

Two sources of DCT chips include *C-Cube* and *SGS*, while some useful (but very much slower) do-it-yourself software routines are shown in the Ciarcia article.

A New Digital Sinewave Generator

Hardware hackers interested in communications are really getting off on a great new integrated circuit from *Micro Linear*. This is their ML2035 Programmable Sinewave Generator. Cleverly disguised as an eight pin mini-DIP, this new chip is an \$8, full performance 16-bit digital sinewave generator. With a real 21-bit phase accumulator and a 9-bit sine lookup table built into it!

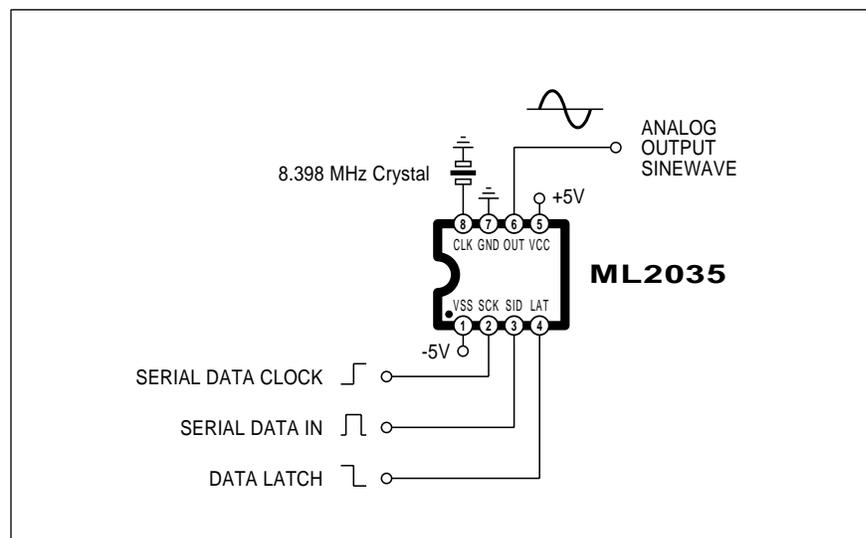


Fig. 4 – A DECEPTIVELY SIMPLE DIGITAL SINEWAVE GENERATOR. This \$8 chip does a full 21 bit phase addition and a 512 level table lookup for an outstanding quality. Resolution is one hertz over a 1 Hertz to 25 kHz range!

SANTA CLAUS MACHINE RESOURCES

Batelle

505 King Avenue
Columbus, OH 43201
(614) 424-7782

CAD/CIM Roundtable

1050 Commonwealth Avenue
Boston, MA 02215
(617) 232-8080

Control Automation

2350 Commerce Park Dr NE, #4
Palm Bay, FL 32905
(407) 676-3222

DTM

1611 Headway Circle B2
Austin, TX 78754
(512) 339-2922

DuPont

1007 Market Street
Wilmington, DE 19898
(302) 774-1000

Freeman Supply

1246 West 70th Street
Cleveland, OH 44102
(800) 321-8511

Grantham/Polly-Stamp

418 Central Avenue NE
East Grand Forks, MI 56721
(218) 773-0331

Industrial Education

1895 Crooks Road S135
Troy MI 48084
(313) 649-4900

Light Machines

669 East Industrial Drive
Manchester, NH 03103
(603) 625-8600

masterCAM

2101 Jericho Turnpike
New Hyde Park, NY 11040
(516) 328-3970

Merigraph/Hercules

300 East Shuman, Ste 260
Naperville, IL 60566
(800) 323-1832

Quadrax

300 High Point Avenue
Portsmouth, RI 02871
(401) 683-6600

Roland Digital

7200 Dominion Circle
Los Angeles, CA 90040
(213) 685-5141

School Shop

Box 8623
Ann Arbor, MI 48107
(313) 769-1211

RA Stewart

641 South Palm, Unit H
La Habra, CA 90631
(213) 690-4445

3-D Systems

26081 Avenue Hall
Valencia, CA 91355
(805) 295-5600

It can easily produce any sinewave from 1 Hertz up to 25 Kilohertz in one hertz steps, and its serial interface mates beautifully with virtually any computer or microcontroller.

Figure four shows the extremely simple circuit. A split supply of +5 and -5 volts is needed. The output frequency resolution will be...

$$f_{\text{out}} = f_{\text{xtal}}/8,388,608$$

Thus, you would use the 8.388608 Megahertz crystal to get a one Hertz resolution. Or you could apply any external frequency up to 12 MHz.

Your output sinewave frequency is determined by the 16-bit digital word you last selected. For instance a digital "1" would get you one hertz, while a "5623" (or a hex \$15F7) will get you 5.623 kiloHertz.

Your output is a clean and low distortion sinewave of around 12 volts

peak to peak amplitude.

In order to save on package pins, your digital control word is entered serially. There are three pins involved. Their SID or *serial input data* pin accepts one data bit at a time, least significant bit first. The SCK or *serial clock* accepts each new data bit on its rising edge. Finally, the LAT or *latch* stores the input serial data stream on its falling edge.

This should interface beautifully with the game paddle port of an Apple IIe, or anywhere else you have three I/O lines available from a computer or microcontroller.

There's also a ML2036 in a larger package with some extra features at slightly higher cost.

One obvious tip: You do input the frequency in *binary* or in *hex*, and not in decimal! Don't laugh. This is a very common hacker mistake.

As a second contest for this month, just tell me something different you would do with this new ultra-cheap, ultra-simple, and ultra-precise digital sinewave generator.

New Tech Literature

Schaevitz has a free *Handbook of Measurement and Control* that gives the fundamentals of LVDT positioning sensors. From *SGS*, a new data book on *Protection Devices* that includes surge and transient suppressors.

Texas Instruments has a new and free linear products sample packet on their *Excalibur* series of JFET operational amplifiers.

Two great new surplus flyers include *Alltronics*, who are big on powerful magnets and computerized hamsters (the dead ones are far cheaper); and *Marlin Jones*, who has some new tilt angle sensors, parabolic mirrors, LCD displays, clutches, and regulators.

Our feature free trade journals for this month include *Circuit Design* on printed circuit layout techniques, and *Nickel*, devoted to stainless steel and all other nickel applications.

Still at the same old stall after all these years, the *Castolite* people offer all sorts of castable resins and mold products. One good way to get started with them is their \$75 product sample and evaluation kit.

The *Circuit Works* people have an interesting conductive pen that writes in silver ink. The main use here is for printed circuit board repairs.

For some additional mechanical stuff, 3M has an interesting brochure on microcapsule technology, while free plastic tubing samples are newly available through *NewAge Industries*. And *PM Research* has a fine catalog on steam engine kits.

Turning to my own stuff, I have combined my seven top hacking books into a *Lancaster Library* at a very special price. These include the *TTL Cookbook*, *CMOS Cookbook*, *Active Filter Cookbook*, *Micro Cookbook I*, *Micro Cookbook II*, *Hardware Hacker II*, and, of course, *The Incredible Secret Money Machine*.

Finally, I do have a new and free mailer for you which includes dozens of insider hardware hacking secret sources.

Write or call for info. ♦

Don Lancaster's Hardware Hacker

December, 1990

Audio Level Meters
A cold Fusion Update
Alternates to Patenting
Understanding Decibels
Wholesale Surplus Sources

As most of you already know, we now provide a no-charge *Hardware Hacker* helpline for you as is shown in the book appendix. Here I can try to show you all the products, resources, publications, and consultant services that might be helpful to you.

But every third day or so I get a call which starts off with "I can't tell you what I'm now working on or what it does..." and then goes on to request something totally absurd.

For instance (and no way could I have made these up), a phase detector with a 143 decibel dynamic range, a fishtank full of hot mercury, a microwave traveling wave tube made from a fluorescent lamp, or a matched quad of high power zener diodes. Or a slow blow fuse to get around a circuit that had an obvious short in it.

To me, paranoid secrecy on any new idea is both asinine and monumentally stupid.

Paranoid secrecy obviously diverts time and energy from improving your product, besides being the inherently evil opposite of what shared hardware hacking is supposed to be all about in the first place. Paranoid secrecy also largely prevents the multi-step, multi-person process that is the essential core of useful product development.

Paranoid secrecy tends to grossly overvalue ideas. Back in the golden age of hardware hacking, well thought out ideas were once worth as much as a dime a dozen. These days, of course, ideas are worth less than ten cents a bale in ten bale lots. It is only when those ideas are converted into actual final products being put to work or play by dozens of happy end users that they gain any value at all.

It ain't creative unless it sells.

Paranoid secrecy discourages the thorough third-party testing of your working models and ongoing beta development prototypes.

Finally, paranoid secrecy virtually eliminates any possibility of selling your product. By far one of the hardest lessons Hardware Hackers have to learn is that *others must come to you*

for your product to be successful. You can't sell to them; they *must* come to you. Always.

So, by all means give me a helpline call *if* you are willing to tell me what you are doing and are willing to share it with others. On the other hand, if you want to attempt to lay a paranoid secrecy fantasy on me, I'd suggest you try one of those 900 number kinky sex lines instead. They would be in a far better position to help you out.

Patents Again

As we've seen a number of times in past columns, any Hardware Hacker involvement with patents in any way, shape, or form, is *absolutely certain* to cause you a net loss of time, energy, money, and sanity.

I recently received yet another sad case for my overflowing patent victim files. But this one's so appallingly bad that it forms a near perfect example of everything *not* to do. This new patentee was wondering why the Fortune 500 companies were not beating his door down, and why he couldn't even get anyone to promote his idea.

Well, for openers, his patent clearly should never have been issued. On the patent side, it had obviously violated a dozen or more fundamental optical control patents held by a major corporation. On the non-patent side, it describes an obsolete concept totally blown out of the water by an industry standard 1952 technical paper, and thoroughly discussed (and dismissed) in a 1973 student textbook.

1. Do not *ever* call yourself an inventor or behave like one. To do sets you up for interminable scams. Instead, you will want to become a product development engineer or a prototyping house.
2. Totally avoid any and all contact with anything even remotely patent related. In any way, shape or form. Do so religiously.
3. Don't bother creating anything in any field in which you are not eventually *certain* to become an expert. An expert who is thoroughly familiar with the technical literature, the history of the field, the marketing realities, the insider trade journals, and the mainstream tools and techniques in use.
4. Publish all your key secrets and ideas in a major magazine, leaving out no detail, and omitting no insider secrets. This immediately can generate positive cash flow for you and safely tucks all your ideas away in the public domain, preventing most others from attempting to patent them. This also exposes your new ideas to the widest possible audience.
5. Try to set up some royalty arrangement with a small to medium firm in some position to market and distribute your invention. The tricky part: *They must come to you*, and *never* vice versa. That is why it is super important to publish your ideas and creations and expose them as widely as possible.
6. Your main defense against getting ripped off in any royalty setup is the expectation that you will be delivering newer and better stuff in the future.
7. Use the shotgun technique. There is no way that one single idea or product will hack it. To survive in this game, you'll need hundreds or even thousands of new ideas and concepts working for you on a total lifetime and total lifestyle basis.
8. Expect to be ripped off. That way, it will be far less of a rude surprise when this inevitably happens to you. And far less of a stress trip.
9. Be realistic. You don't create things to get filthy rich. You create things because you like to create things and have some compelling desire or need to do so. As long as there are enough nickels to keep going, that is all that should really matter.

Fig. 1 – SOME THOROUGHLY TESTED and hacker friendly alternates to patents and the patenting process.

- 60 Decibels is a **1000:1 amplitude gain**.
- 40 Decibels is a **100:1 amplitude gain**.
- 20 Decibels is a **10:1 amplitude gain**.
- 18 Decibels is an **8:1 amplitude gain**.
- 12 Decibels is an **4:1 amplitude gain**.
- 10 Decibels is roughly a **3:1 gain**.
- 6 Decibels is a **2:1 gain**.
- 3 Decibels is about a **30 percent gain** and the **double power point**.
- 2 Decibels is a **20 percent amplitude gain**
- 1 Decibels is a **10 percent amplitude gain**.
- 0 Decibels is a **unity amplitude ratio of 1:1**.
- 1 Decibels is a **10 percent drop**.
- 2 Decibels is a **20 percent drop**.
- 3 Decibels is about a **30 percent drop** and the **half power point**.
- 6 Decibels is **half amplitude**.
- 10 Decibels is around **one-third amplitude**.
- 12 Decibels is **quarter amplitude**.
- 18 Decibels is **eighth amplitude**.
- 20 Decibels is a **10:1 attenuation**.
- 40 Decibels is a **100:1 attenuation**.
- 60 Decibels is a **1000:1 attenuation**.

Fig. 2 – SIMPLE RULES that make using decibels a lot easier.

While the idea purports to be a micropower one, it requires the continuous application of very precisely regulated high energy levels. While it is supposed to be microminiature, a complex mechanism is involved. And multiplication is introduced at crucial

points in the circuit where outstanding linearity is an absolute must.

Despite it being something that any of you could easily beat out on the kitchen table, it is obvious that the idea was never tested in a final use application. Nor could any possible

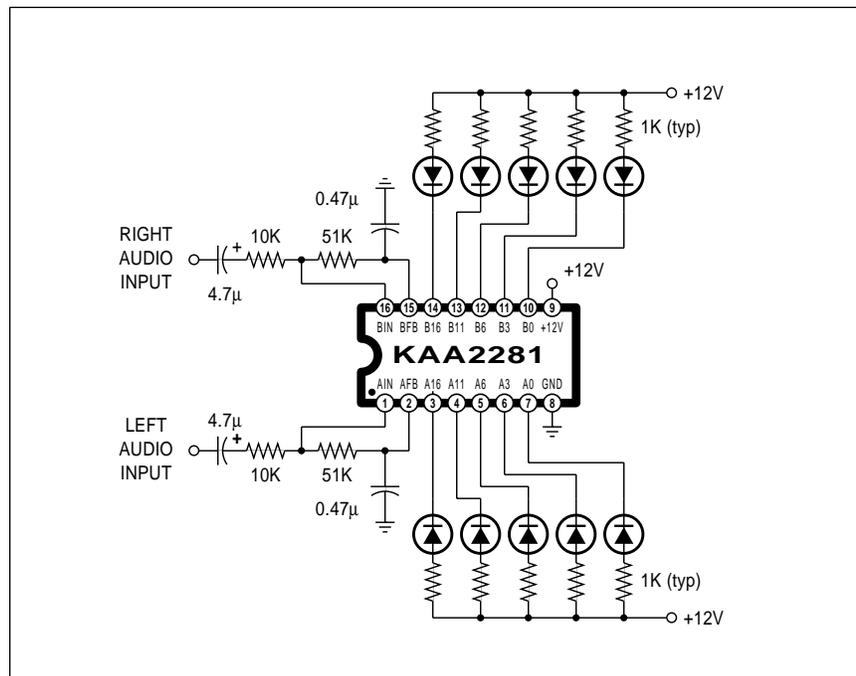


Fig. 3 – A STEREO AUDIO LEVEL METER using the Samsung KAA2281. Levels displayed are -16, -11, -6, -3, and 0 decibels.

end user or builder of this product ever have been so much as contacted, let alone consulted.

I sorely wish this was an isolated example, but it is now one of hundreds in my victim files that collectively have cost all you hackers many millions of dollars. *Not once* have I ever seen *any* example of anyone who has profited in *any* way from *any* patent involvement from within a small scale hardware hacking environment.

So what are the alternatives? Figure one shows you some patent avoidance guidelines that may help you.

We've plowed some of this ground pretty well in the past. But one thing I'd like to emphasize here is that you can *never* develop and market an idea as an outsider. To develop and market something that's useful, you *must* be thoroughly familiar with that field's technical literature; its history; all its marketing realities; the mainstream tools and techniques; and, above all, the insider trade journals involved.

For instance, there is absolutely no way you should be writing forest fire simulation software if you have never sharpened a *Pulaski*. Working with active filters is pointless if you have never met *Sallen and Key*. And developing unfocused solar collectors without *Winston* is unthinkable.

I once had a long talk with a retired patent examiner who carefully went back over his thirty years experience and tried to find out just how many individuals *acting alone* were successful with a strategy of "patent an undeveloped and unproven idea as an outsider and then try to sell it somewhere." The answer: *Not one ever!*

For more on patents and patenting, see *The Case Against Patents* in the December 1990 *Midnight Engineering* (now in GENie PSRT library as #162), or read my *Incredible Secret Money Machine* book.

An Audio Level Meter

As we've seen a time or two in the past, the new three volume *Linear IC Databook* set from *Samsung* has been crammed to the rafters with top notch hacker integrated circuits. For this month, I thought we might take a look or two at several of their audio level indicator chips.

But first, let's go over some fundamentals. You will often find two

popular ways of dealing with any electronic or physical quantity, *linear* and *log*, short for logarithmic.

The linear scale has equal steps everywhere in it. Obvious examples include a ruler where your distance between 1 and 2 is exactly the same as the distance from 8 to 9. The channels on the AM radio dial are also linearly spaced with frequency, each being 10 kilohertz above or below its nearest neighbor.

Now linear sounds great, and it is the *only* way to go if you want to prevent any interaction or any multiplication or distortion should two or more quantities of something both be present at once. But, if you attempt to go too far with a linear scale, one end or the other ends up far too cramped or way too spread out. Put another way, the *dynamic range* of a linear scale or system is often limited.

The log system instead works with *constant percentage* scales. Equal anything's are close together on the "low" end and further apart on the "high" end. For instance, the notes on a musical instrument are usually a tad under six percent above or below one another. Or, more precisely, we are dealing with the twelfth root of two, or 1.059545, since the frequency of your notes doubles as you go up a twelve note *octave*, or 2:1 frequency.

Log systems will often have a much higher dynamic range than the linear ones. And there's lots of places where "equal change" is more important than "equal steps."

For instance, rank beginners are often mystified why standard resistors do not simply go 1.0, 2.0, 3.0, 4.0..., instead of 1, 2.2, 3.3, 4.7, 6.8....

Obviously, we are dealing with a log scale here. First, because you'll normally want to cause a constant percentage change when you alter a resistor in an electronic circuit. And secondly, because stocking different resistors in one Ohm increments up in the megohm range quickly would get out of hand.

Some physical systems are inherently logarithmic. In fact, anything linear over a wide range in the real world is usually the exception rather than the rule.

The ear is a log system, allowing it to deal with everything from a whisper to a shout over an incredible dynamic

range. And since radio began with audio, it is convenient to employ log systems to describe the differences between powerful transmitted signals and weak received ones.

All of which leads us around to *decibels*. Decibels are simply one convenient way of measuring things on a log scale with a potentially wide dynamic range. Since you'll usually measure voltage rather than power, most hackers most of the time go with voltage decibels rather than the much rarer power ones.

A reading of so many decibels tells you the *relative* strength between two quantities. For instance, a one decibel change is around a ten percent change in amplitude. It is also roughly the smallest amplitude change you can usually pick up with your ear.

A two decibel change is around twenty percent, and a three decibel change is around thirty percent. More specifically, when one signal is at a -3 decibel level from another, (or "three db down"), you will be at 0.707 relative amplitude.

Now, since power is related to the square of your circuit voltage, and since 0.707 squared is 0.5, being three decibels down also is at *half power* from whatever your 0 decibel level happened to be.

Hi-fi components normally have their frequency responses specified between their upper and lower -3

decibel points. Put another way, this is the range over which the available power remains over half of what you would get in the "middle" of whatever frequency range you're measuring.

Moving right along, a ten decibel change is roughly a 3:1 amplitude ratio, twelve decibels is one quarter, eighteen decibels is one eighth, and twenty decibels equals one tenth. One hundredth is forty decibels, and one thousandth is sixty decibels. The 143 decibel phase detector asked for above is the ratio between one microvolt and fourteen volts, an almost impossible dynamic range to deal with gracefully at reasonable cost in the real world.

I've gathered some of these "rule of thumb" decibel ratios into figure two for your reference.

Once again, most all of your decibel measurements are *relative* and will always refer to two different levels in two points in your circuit. Decibels usually answer the question "How strong is the present signal or response compared to another one?"

How strong is a six decibel signal? Somewhere between a femtowatt and a gigawatt, at least sometimes. Maybe. It all depends. All we know for sure is that this particular signal is twice as strong in amplitude as some other one at some other time or place. For an amplifier with a 20 decibel gain, we know that the output will be ten times as strong as the input amplitude, at

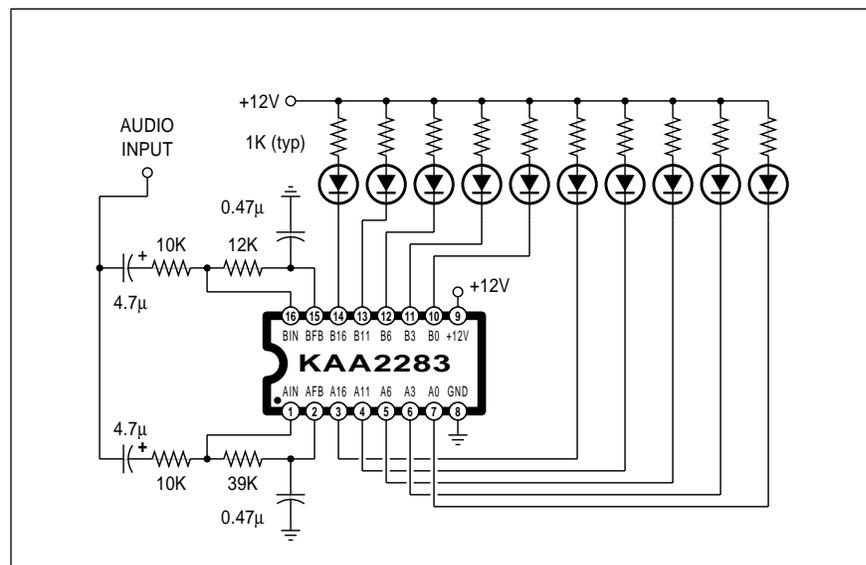


Fig. 4 – A MONO AUDIO LEVEL METER can be built by using both halves of the Samsung KAA2283. Levels displayed are -18, -16, -14, -12, -10, -8, -6, -4, -2 and 0 decibels. Sensitivity is from 0.1 to 0.9 millivolts.

least over the intended working levels of your circuit.

Audio engineers will sometimes refer decibels to a very specific voltage level over a specified impedance. They will then use the term DBM to specify such an absolute level. One milliwatt into a 600 ohm line is one possible absolute DBM level. Here you are comparing the ratio of your signal against the standard reference, rather than another signal.

But the stereo, hi-fi, and the home recording people have long since bastardized the meaning of the term DBM. Today, unless you are certain you are dealing with the professional studio audio standards, an apparent 0

DBM is just the maximum allowable voltage level at some point in some circuit above which the distortion levels are no longer acceptable.

Thus, while your VU, or *volume units* display on a receiver or recorder does in fact measure some absolute voltage level, the chances are your particular VU units have nothing to do with anyone else's. All they are is a reference level above which distortion will start to become unacceptable.

Samsung has a bunch of level meter driver chips that are simple and easy to use. Note that these all differ from a "bargraph" driver in that the bargraph works in linear steps and the level meter driver works in the log steps.

Figure three shows you the KA2281 which offers internal trip levels of -16, -11, -6, -3, and 0 decibels and gives you two stereo channels that can power five lamps each.

Note that some commercial units will cheat and assign a *pair* of light emitting diodes to each output, giving you the *illusion* of ten steps when you really only have five.

Figure four shows you the similar KA2283 which uses levels of -8, -6, -4, -2, and 0 decibels instead. This time, I've shown you how to attenuate one side to make a single channel ten lamp display. You might want to make your lower level LED's green, a middle one yellow, and use reds for the upper ones for an additional effect.

In this particular circuit, less than 100 millivolts of input lights nothing and more than 900 millivolts lights everything. You can easily change the input attenuators to pick up other operating ranges. Note that the bottom half of the circuit has to attenuate ten decibels more than the upper one to keep all of the steps equal.

Cold Fusion Update

What ever happened to cold fusion? Well, Uh, Um, Er.... Two years have gone by and cold fusion remains what it started out as... a largely unduplicatable lab anomaly in which some apparently excess unexplainable heat sometimes appears.

Since there seems to be an ongoing glut in the lab anomaly market, most interest in cold fusion has, to say the least, waned.

However; there remain bunches of dedicated true believers continuing to do high quality research in the cold fusion area. The leading source for professional papers on cold fusion is that *Journal of Electroanalytical Chemistry*, a Swiss publication.

A few of their more important cold fusion papers are listed here for you in figure five.

This Month's Contest

One thing I like to do every now and then is pick up a magazine on some hobby or industry that I'm not in the least into. More often than not, you can find unusual ads, ideas, techniques, or mindsets that end up surprisingly relevant to your own trip.

For instance, we've seen in the past

- Electrochemically induced nuclear fusion of deuterium.**
Fleishmann, Pons, Hawkins, vol 261 pp 301-308.
- Examination of nuclear measurements in cold fusion experiments.**
Abriola, et.al, vol 265 pp 355-360.
- Observations of the surface composition of palladium cathodes after electrolysis.**
Mebrahtu, et.al, vol 267 pp 351-357.
- Electrochemical incorporation of lithium into palladium from aprotic electrolytes.**
Dalard, et.al, vol 270 pp 445-450.
- Production of tritium from electrolysis at a palladium cathode.**
Packham, et.al, vol 270 pp 451-458.
- A long-term calorimetric study of electrolysis using palladium cube cathodes.**
Armstrong, et.al, vol 272 pp 293-297.
- Tritium production during the cathodic discharge of deuterium on palladium.**
Chene, et.al, vol 280 pp 199-205.
- Electrochemical fusion: a mechanism speculation.**
Lin, et.al, vol 280 pp 207-211.
- Tritium separation during heavy water electrolysis: implications for cold fusion.**
Corrigan, et.al, vol 281 pp 305-310.
- Experimental investigations of electrolysis using palladium cathodes.**
Zahm, et.al, vol 281 pp 313-319.
- In-situ measurements of deuterium uptake in palladium using diffractometry.**
Bennington, et.al, vol 281 pp 323-328.
- Surface and electrochemical characterization of Pd cathodes after charging.**
Ulmann, et.al, vol 286 pp 257-263.
- Morphological difference between hydrogen-loaded and deuterium-loaded palladium.**
Rolison, et.al, vol 287 pp 375-384.
- Local heat effects by electrolysis of heavy water.**
Ratkje, et.al, vol 273 pp 269-273.
- Energy balance in the electrolysis of water with a palladium cathode.**
Rock, et.al, in press.
- A critical analysis of electrochemical nuclear fusion experiments.**
Kreysa, et.al, vol 266 pp 437-450.
- Hydrogen and oxygen recombination in calorimetry of water electrolysis.**
Cunnane, et.al vol 269 pp 163-174.
- Experimental investigation of thermal and radiation effects by deuterium discharge.**
Chemla, et.al, vol 277, pp 93-103.
- Energy balance of electrolysis with a palladium cathode, Part I, Theoretical relations.**
Balej, et.al, vol 278 pp 85-98.
- Energy balance of electrolysis with a palladium cathode, Part II, Experimental results.**
Divisek, et.al, vol 278 pp 99-117.
- Absorption of electrolytic hydrogen and deuterium by Pd: cyanide adsorption.**
McBreen, et.al, vol 287 pp 279-291.
- Calorimetry of the palladium-deuterium-heavy water system.**
Fleischmann, et.al, vol 287 pp 293-348.

Fig. 5 – SOME KEY PAPERS ON COLD FUSION that have recently appeared in the Journal of Electroanalytical Chemistry.

how *Model Railroader* is one outstanding source of unusual tools and techniques. They also occasionally get into casting compounds and photo-chemical machining. I think that MR has by far the finest technical writing of any publication anywhere ever on any level, and should be mandatory reading for any tech writer.

Some day, I hope to eventually be able to write that good. Maybe with some more experience...

Another magazine which recently caught my eye was *Radio Control Modeler*. Again, lots of unusual tools and techniques. I'm wondering what happens when you use what these folks call a *heat sealing iron* for *Kroy Color* or for circuit board dry resist laminating. The R/C people are also into amateur television stuff.

But what I noticed the most (and this is probably ancient history to a R/C buff), is that these hobbyists now are building models at *one quarter scale*. No, not quarter inch scale, but quarter scale. Something like a P-51 Mustang model can run a wingspan of 110 inches or so. And the models are infinitely cheaper than a real airplane. A few hundred dollars (less with lots of hands-on effort) and you are in the air. Quickly and cheaply.

Now, any quarter size aircraft can hoist a respectable payload and carry it an acceptable distance. At costs that are ridiculously lower and far less regulated than "real" aviation.

Uses? For video obviously. But less obvious would be such things as cave hunting, either by the regular stereo photography for sinkhole searches in difficult terrain, or with infrared film to attempt to find "near" entrances on bitter cold days.

So for this month's contest, tell me what you would do with an aerial platform that can handle a respectable payload. Let's go well beyond chopping holes in the *Goodyear* blimp (as was recently done), the nudist colony jokes, and drug deliveries. Limit all your responses to largely legal and purportedly more noble endeavors.

There'll be all the usual *Incredible Secret Money Machine* book prizes for the top dozen entries, along with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best. Be sure to send all your written entries directly to me at *Synergetics*.

WHOLESALE SURPLUS SOURCES

Ace Electronics

3210 Antoine
Houston, TX 77092
(713) 688-8114

ACP Components

1317 East Edinger
Santa Ana CA 92705
(714) 558-8822

All Components

5999 Summerside #208
Dallas, TX 75252
(800) 367-7312

American Design

Box 220
Fairview, NJ 07022
(800) 776-3800

Braniff Industries

91 South Ottawa
Dixon, IL 61021
(815) 288-4500

Calcera

PO Box 489
Belmont, CA 94002
(800) 257-5549

Dorf Electronics

1 Biehn Street
New Rochelle, NY 10801
(800) 431-2912

H&R Enterprises

21521 Blythe Street
Canoga Park, CA 91304
(818) 703-8892

Japan Electronics

15138 Valley Blvd
Industry, CA 91744
(818) 369-5000

J&C Electronics

Box 630
Salem, MA 01970
(800) 447-7014

Jerome Industries

8737 Shirley Avenue
Northridge, CA 91324
(818) 993-1393

Leo Electronics

22353 S. Western #201
Torrance, CA 90501
(213) 212-6133

Micro-C

11085 Sorrento Court
San Diego, CA 92121
(619) 552-1213

Microprocessors Inc.

24000 South Peoria
Beggs, OK 74421
(918) 267-4962

New England Circuits

292 Cabot Street
Beverly, MA 01915
(800) 922-NECS

Oracle Electronics

1355 Adams Court
Menlo Park, CA 94025
(415) 326-2660

Search Electronics

228 East Atara
Monrovia, CA 91016
(818) 359-3350

Southwest Memory

3939 Beltline Road #775
Dallas, Texas 75244
(214) 484-1595

Surplus Traders

Winters Lane Box 276
Alburg, VT 05440
(514) 739-9328

World Wide

18 Stern Avenue
Springfield, NJ 07081
(800) 222-6268

Wholesale Surplus Sources

Have you ever wondered where the surplus houses go to buy their stuff? Few hackers realize there is a lean and mean collection of small outfits out there collectively known as *wholesale surplus dealers*.

All of the good news here is that outstanding prices are the norm. Two cent integrated circuit sockets, three cent LED's, quarter motors and fifty cent EPROM's are routine. The bad news is that you can only buy using stiff lot, line, or total order minimums. There is also no technical support or hand holding whatsoever.

Our resource sidebar for this month shows you several of the better known wholesale surplus sources. These and others often advertise in the classified sections of *Electronic News* and the *Electronic Buyer's News* magazines. Except for *Surplus Traders*, virtually none of these offer catalogs. Some provide FAX current availability lists, while others prefer to bid on your custom list of specific needs.

The foremost rule in dealing with these folks is *no messing around*. The preferred contact means is by FAX, and most quotations are only good for twelve minutes or so. Quick cash sales are the norm.

As with any surplus, items quickly go in and out of popularity and may vanish entirely. Prices can suddenly skyrocket should the non-surplus lead times lengthen. Quality also can range from absolutely first rate to useless floor sweepings. Buyer beware.

New Tech Literature

Some ancient hacker construction projects on those solid state vortex coolers we recently looked at include the November 1947 issue of *Popular Science*, and chapter 4 of the *Scientific American Amateur Scientist* reprint volume from the early 1960's.

Two interesting ap notes are the *Introduction to Infrared Pyroelectric Detectors* from *ELTEC* on the people motion detection, and the *Best of the Trimmer Primers* from *Bourns* on the use of precision trimmer pots. ♦

Don Lancaster's Hardware Hacker

January, 1991

Low cost visible lasers
Electric motor resources
Induction motor controls
New wavelet math theory
Dual digital potentiometer

Let us start off this month's column with a very hackable circuit opportunity that has not quite seen the light of day. At least not yet...

Induction Motor Speed Controls

Why should it be cheap, easy, and trivial to regulate the speed of your electric drill, yet super expensive and next to impossible to control the speed of a compressor or blower motor on an air conditioner? After all, a motor is a motor, isn't it?

Sadly, the answer is no. Those AC induction motors simply were never designed to have their speed changed, and they throw all sorts of really ugly hassles at you when you try to do so. Let's see why this is so.

Just about all electric motors are based on two fundamental electrical principles. The first of these is that *like magnetic poles repel and opposite ones attract*. The second is known as *Fleming's Rule*, which states that *a current carrying conductor at right angles to a magnetic field will produce a force and attempt to move in a direction at right angles to both the magnetic field and the current*.

When using conventional current, this produces the familiar *right hand generator rule*, wherein your thumb points in the direction of the motion, your index finger towards the south pole of the magnetic field, and your middle finger in the direction of the conventional current.

For a motor, the same rule applies to your left hand. The only theoretical difference between a motor and a generator is that you input motion to get an output current with the generator, while you input current to get a force and hopefully a motion with a motor. In reality, all motors do some generating, and vice versa.

So, your only trick to building a motor is to constantly rearrange your magnetic fields and their strengths so they are either attracting one another or shoving each other away. Or use some ongoing combination of *attraction and repulsion* together.

A motor usually will consist of a stationary part called a *stator* and a moving part known as a *rotor*.

Another name for the rotor is an *armature*. If it gets necessary to physically transfer current to your rotor, either *brushes* and a *commutator*, or else *slip rings* can be used. Slip rings apply continuous power to your rotor, while fixed brushes and a commutator selectively switch in and out chosen windings that happen to be aligned with the brush axis at any particular point in time.

You'll find quite a few different possible motor designs. But by far the two most economically important are that *series DC motor using brushes*, which is sometimes called a *universal motor*, and the *AC induction motor*. Let's look at each one in turn.

Figure one shows you a universal motor and its torque versus speed curve. You'll recognize this one in your electric drill, any hot tub blower, vacuum cleaner, blender, sewing machine, or older car starter.

There is a pair of wound stator coils that (when run on dc) will produce a constant stationary magnetic field. In series with the stator coil is a pair of brushes with a commutator, which

selectively switch rotor windings in and out so that one or more windings is constantly getting attracted to the fixed stator field. As your armature rotates, new windings get switched in by the commutator, so that a more or less continuous attraction, and thus a rotary motion gets produced.

The same universal motor works almost as well with ac, except that sometimes you have strong fields and sometimes weak ones as the current alternates. Usually, the mechanical inertia of your load will more or less average all these variations into continuous rotary power.

Even with AC, you still always have opposite poles attracting one another. They just happen to alternate their polarity 120 times a second. But they always change together.

Note that you could reverse your universal motor by placing a DPDT switch between the commutator and the stator coils. But this can cause excessive wear if the motor brushes were not designed for two-way use.

As your universal motor slows down, its torque will increase. This tends to add to the motor *stability*. As you slow down, the available "twist" increases to speed you back up, and

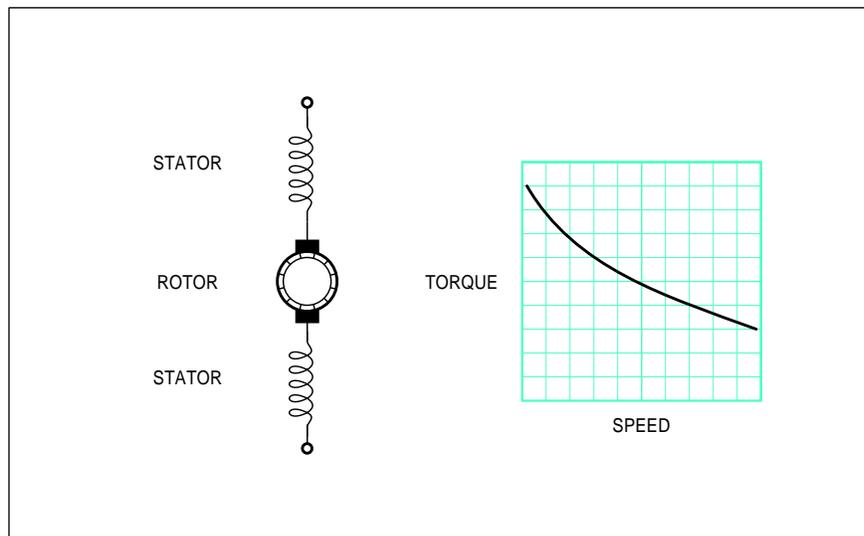


Fig. 1 – A UNIVERSAL SERIES motor with brushes as is found on an electric drill, along with its speed-torque characteristics. The speed is easily and electronically controlled by using simple circuits.

vice versa. Self regulating.

Since you have lots of torque at zero speed, your motor self-starts. It might overheat badly if you stall it permanently. But, given half a chance, a universal motor easily gets itself up to speed. And stays there.

Any motor is simultaneously a generator, and vice versa. A universal motor that is lightly loaded and running at a high speed produces an output voltage and resultant current in *series* with your input current. This voltage generated is known as a *back emf*, which *opposes* the input current. When lightly loaded, very little current is drawn from the supply, since the back emf and its resultant current nearly cancels out the input current.

Which is real handy from a conservation of energy standpoint. If you are doing no useful work, and if your motor isn't getting particularly hot, then you should not need too much input energy just to spin things.

As you add mechanical load, your series machine will become less of a generator and more of a motor. The back emf and its cancelling current drops, and the input current goes up. Your new energy needed is mostly transferred to your mechanical load. Again by conservation of energy, you are putting more energy in so you can get more energy out.

Neglecting nonlinearities such as air resistance, *the speed of a universal motor for a given load is determined*

only by the input current. You raise your current to go faster; reduce it to slow down.

Which says you can just throw any old high power resistor in series with your universal motor to control its speed, just like used to get done on sewing machine motors. Better yet, you can use a far more efficient *triac* style light dimmer for control.

Or, best of all, you can sense that back emf or otherwise measure your actual motor speed and use electronic feedback with a triac or SCR circuit which is only slightly more complex than a plain old dimmer. This gives you a tightly regulated speed control plus the ability to run real slow with lots of torque.

The bottom line is that it is trivial these days to electronically regulate the speed of a universal motor. We've seen several circuits in past issues and in those *Hardware Hacker II* reprints. They are also ten bucks at your hardware store or \$3.95 surplus.

As we have seen, *LSI Systems* is a good source for fancy universal motor controller chips, while lots of detailed ap notes appear in the usual triac data books from *Motorola*, *SGS*, *Texas Instruments*, and several others.

So what is wrong with universal motors? If they are so universal, why aren't they used everywhere?

The biggest problem lies in those brushes. Brushes wear out. They are inefficient. They are both acoustically

and electrically noisy. They spark and can start fires or explosions. And these problems really get out of hand when you need more horsepower.

Look around, and you'll see that virtually all universal motors in your home are only run on an *intermittent* basis. Mostly because your brushes cannot be run continuously without grinding themselves into oblivion. Or driving you up the wall with noise.

Ideally, we would like to conjure up some scheme to get power onto the rotor without any brushes or other physical contact. And that's where the induction motor comes in.

Figure two shows us a brushless beastie known as an *AC synchronous motor*. It has a wound stator and a permanent magnet rotor. Assume that we are plugged into the 60 Hertz ac line and that the rotor just happens to already be spinning at 3600 RPM.

On a positive line peak, the north magnet pole will get attracted to the upper stator coil. By the time your magnet is pointing straight up, the current will be going through zero and there will be no mutual attraction or repulsion. Soon afterward, the line current swings negative, and that opposite polarity starts repelling the magnet, continuing it on its merry way. The exact opposite happens to the other pole, and the motor will continue to spin.

The *synchronous speed* is set *only* by the number of poles and the line frequency, and is *totally independent* of your input current. The two pole synchronous motor runs at 3600 RPM off the 60 Hertz line; a four pole job spins at 1800 RPM, and so on.

We thus see that a synchronous motor is real handy for maintaining a constant speed. Important use areas are for electric clocks, phonograph motors, timers, chart drives, and other lower power uses where an absolutely constant speed independent of the load or input current is essential.

What happens when we apply too much of a load? If your magnet gets 90 mechanical degrees out of phase, there will be no attraction or repulsion, and zero power routed to the load. If it gets further out of phase, it actually tries to stall itself. Thus, the slower the speed, the less the torque.

You really have a two speed device here – 3600 RPM and 0 RPM. One con-

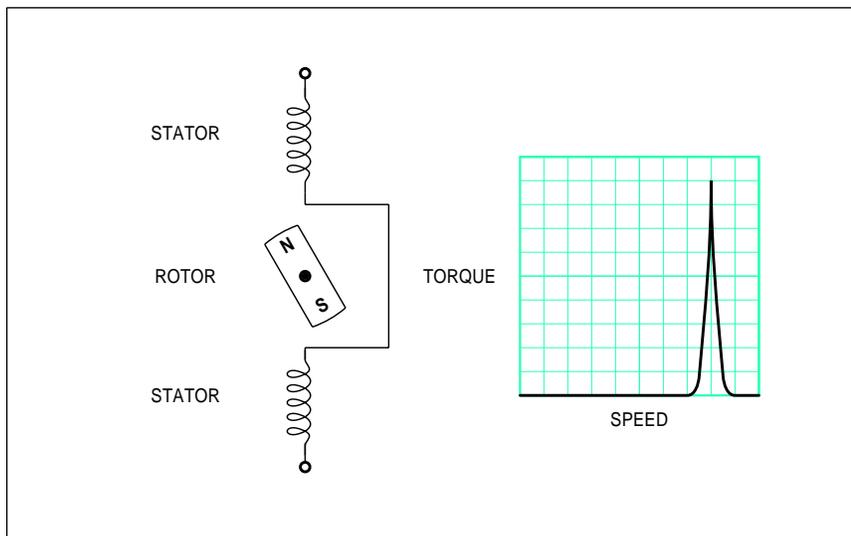


Fig. 2 – A SYNCHRONOUS AC motor as is found on an clock, along with its speed-torque characteristics. The speed is determined only by the line frequency. The input current only determines how strong a load can be driven.

sequence here is that *any true single phase synchronous motor will not start by itself*. You will have to help it along with some switchable starting winding, a pole shading, an ferrous hysteresis cup, or a second or a third winding driven from a two phase or three phase source.

A second consequence is that the *speed of a synchronous motor with varying load or current could end up unstable*. If it ever breaks out of sync, you almost surely will stall. This happens because a slowdown produces less torque, which in turn will produce less speed. Just the same as an auto in too high a gear for the grade will buck or stall.

The load current does decide how large of a load could get driven at the synchronous speed. The more input current, the more power you could deliver to the load without breaking your synchronization.

Figure three shows us a variation on a synchronous machine known as the *AC induction motor*. This one is by far the most common motor in use today. You will find these on your air conditioners, heater blowers, washers, most table saws, dishwashers, dryers, drill presses, water pumps, and many circulation fans.

These are also the ones you would most like to be able to cheaply control the speed of. Especially to raise the efficiency of heating and cooling.

The concept for the ac induction motor was positively brilliant. Tesla strikes again. Somehow you have to get currents onto the rotor, but we definitely want to avoid any brushes or other mechanical contacts.

Question: What do you have when you have coils and iron driven from an AC current? Answer (A): a motor. Or (B): a transformer (!).

Instead of brushes or slip rings, you *transformer couple* the rotor current in an induction motor. This is usually done by creating a special low impedance transformer secondary known as a *squirrel cage*. The purpose of the squirrel cage is to serve both as the transformer secondary and as rotor coils to simulate the rotor magnet of figure three.

But not so fast. Literally. If you are running at synchronous speed, no lines of flux will be cut, and there will be no current induced into the squirrel cage.

Which gives you synchronous speed, but zero power. Now, let your speed *slip* just a little bit. There is now a very *low frequency* ac current induced in the squirrel cage. This does create a changing magnetic field, and you now have more torque than you do at synchronous speed.

Lower the speed slightly more, and you create even more torque. But slow down too far, and your torque starts dropping radically.

Thus, an AC induction motor has optimum torque at a speed which is only modestly less than synchronous. Which is why your "quarter horse" motor is usually rated at 3450 RPM for a two pole motor and 1734 RPM for a four pole one.

As you can see, we have a well behaved torque-speed curve between the synchronous speed and the optimum *but only slightly slower* peak torque speed. Below this peak speed, you'll have the same instability and dropout problems that you'd have with a pure synchronous machine.

Like a synchronous motor, a single phase induction motor will not start itself. Usually there will be a second *starting winding* that gets kicked in only when getting the motor up to speed. Other starting variations can

include a pole shading or multiple phase windings.

In theory, you could reverse your induction motor by reversing the direction the starting method shoves the rotor. Details vary with the motor type. In some cases, the only way to reverse the motor is to remove the rotor and put it back in pointing the other way.

Another problem with induction motors is that the optimum motor speed is usually far too fast for useful real-world work. You almost always have to use pulleys and belts or some other speed reduction scheme. Or go to lots and lots of poles, as is done in those fancy ceiling fans.

Thus, *any attempt to control the speed of an induction motor with a series resistance or a simple phase control is doomed to failure*. This flat out will not work and probably will burn up your motor as well.

Its like plowing with a pig.

Now, you *can* use current control to alter the speed of your motor between its synchronous speed and its slightly slower optimum speed. But this range is usually far too narrow to be useful.

Unless you are willing to vary the *frequency* applied to your motor. But since the impedance of a motor varies

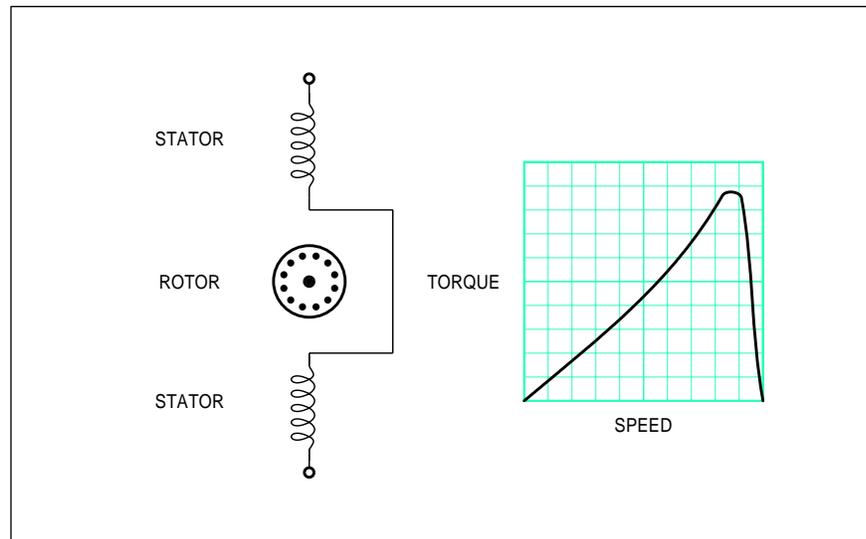


Fig. 3 – AN AC INDUCTION MOTOR as is found on a washing machine, along with its speed-torque characteristics. The current only controls the speed over a very narrow range between the optimum slip speed and the synchronous speed. To control the speed of this type of motor over a wider range, you have to use a complex cycloconverter circuit that can change both the input frequency and current, as well as accurately measuring the speed. You also have to be sure your starting windings (not shown here) do not cut back in at lower speeds.

with frequency, you'll also want to vary the voltage or the input current as you change frequency. Keeping the magnetic flux at a constant strength seems like a good starting point, so raising the voltage with the line frequency seems like a good idea. You'll also have to quite accurately sense your motor speed at all times, and feed back all of this information into your controller.

In addition, you do have to guarantee that the starting windings or whatever do not kick in at slower speeds. Most starting windings are for very intermittent duty only and will rapidly burn up if run continuously.

Circuits which sense motor speed and vary both the frequency and the current are often known as *cycloconverters*. Yes, you can get them. One major supplier is *Asea Brown Boveri*, a Swiss firm having a wide range of induction motor speed controls. But they are not cheap. And cycloconverter controlled induction motors tend to whine a lot, owing to nonlinear magnetic harmonics in the mid audio range. Tweeeeeee.

But a \$19.95 wide range and quiet

quarter horse induction motor speed control is not likely to show up in your hardware store in the next few months. Even though we do have bunches of better magnetics and new intelligent power integrated circuits available that should make the task far easier than it once was.

What you are more likely to see are modifications to traditional induction motors which can make them more amenable to electronic speed control. Such things as dual stators, variable frequency rotors, and internal speed sensors.

The bottom line? A lot of thought and time and effort has gone into induction motor speed controls for several decades now. So far, nothing really useful has yet seen the light of day. Despite an incredibly big bag of nickels waiting for the winner.

I strongly urge you to try and hack this one. But don't expect any prompt or easy results. Needless to say, we here at **Radio-Electronics** editorial will pay very well for the first hackable, wide range, and sanely priced quarter horse induction motor speed control construction project.

Electric Motor Resources

To get you started, I've put together some *electric motor resources* for you in the resource sidebar for this month. Here's a quick rundown...

One very good starting point is the \$5 *Small Motor and Gearmotor* handbook from *Bodine*. *W.W. Grainger*, of course, is by far the leading wholesale distributor of just about any type of small motor. And your best source for electric motor hacking books remains *Lindsay Publications*.

Good surplus motor sources include *C & H Sales*, *Northern Inc.*, *JerryCo*, *Herbach and Rademan*, and *Fair Radio Sales*. Two of the higher volume suppliers of smaller motors are *Molon* and *Fasco*.

As we have just seen, one international source for ac induction motor speed controls is *Asea Brown Boveri*.

Important trade journals involving motors include *Motion*, *PCIM*, *Machine Design*, *Appliance*, *Appliance Manufacturer*, and *Design News*.

Some of the more scholarly stuff comes down in either of the *IEEE Transactions on Energy Conversion* or their *IEEE Transactions on Industrial Applications*. For automotive motor uses, try the publications in the SAE library.

Uh, even though this is one of our longer resource listings, I've got a hollow feeling I am missing several major and obvious motor hacking resources here. Something that you electrical types out there might be able to help us on.

So, for the first of this month's contests, let me know what I've left off the sidebar in the way of motor resources. They'll be all the usual *Incredible Secret Money Machine* book prizes, along with an all expense paid (FOB Thatcher, AZ), *tinaja quest* for two going to the best entry of all.

Or, as a second contest, just add to our ongoing induction motor speed control dialog in some useful way. As usual, be sure to send all your written entries directly to me at *Synergetics*, rather than over to **Radio-Electronics** editorial.

A Dual Digital Potentiometer

A ways back (Jan 89) in the *Hardware Hacker II* reprints, we looked at a *Xicor X9103* digitally controlled 100

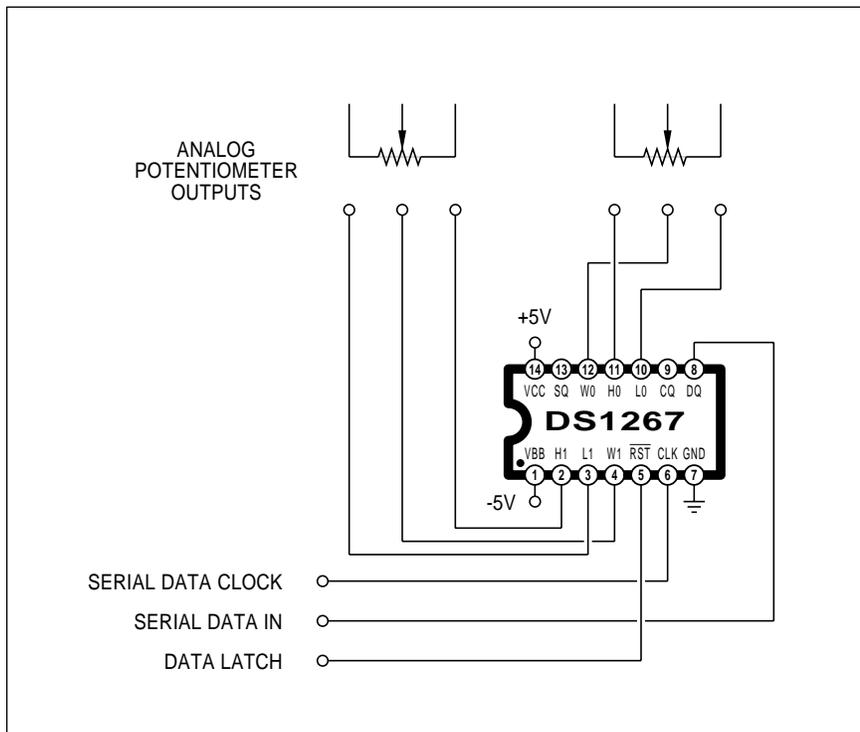


Fig. 4 – A DUAL DIGITAL POTENTIOMETER using the Dallas Semiconductor DS1267. A 17-bit serial word determines which of the 256 steps for each pot gets selected. Unlike EEPOT chips, the settings are easily read but forgotten on power down. A CQ serial output lets you daisy chain your digital commands.

step potentiometer. This dude was a single channel device, had a permanent memory that remembered even when it was unpowered, and let you increment or decrement the pot setting with a simple interface. But it had no way to sense the present setting, nor any way to jump to any setting without moving through all of the intermediate ones. Sequentially.

Dallas Semiconductor has just introduced a new DS1267 dual digital potentiometer chip that has strengths where the X9103 was weak, and vice versa. As figure four shows us, this one gives you two 256 step pots in a single package in your choice of 10K, 50K, or 100K total resistance.

These are *not* memory devices. They return you to a 50% "mid-wiper" position on power up and *must* get rewritten each time. As is becoming common on many new chips these days, there is a three-wire serial control provided, intended to interface with three computer port lines.

To set up your pots, you clock in seventeen data bits by using the CLK and DQ lines, while keeping the RST line high. Eight of these bits are for the first pot, eight for the second, with the final bit being used to optionally cascade the pot pair into a single pot with 512 steps of resolution.

Drop the RST line to enter the new settings for the potentiometer pair.

There's also a serial OUT that lets you read out the present settings or else cascade chips for such things as multi-band equalizers.

As long as RST remains high, your old setting gets saved. Thus, you can do 17 clocks to read out your existing settings, and 17 more to enter the new ones, without any noise or glitches.

The digital end of the chip works off your usual 0 and +5 volts. The analog end can be anywhere from 0 to +5 volts with a grounded VB substrate pin, or can be used over a -5 to +5 range with -5 on your substrate pin. Thus, you can easily handle bipolar analog signals that go above and below ground.

Your max clock frequency is 10 Megahertz, meaning that you can upgrade your pot settings as often as 580 Khz or so. Their series wiper resistance is typically 400 ohms, and you are allowed a max potentiometer or wiper current of one milliampere.

Be sure to see the data sheet for additional specs and timing details.

For our third contest this month, just tell me what you would do with one or more cascaded dual digitally controlled potentiometers.

Making Wavelets

There is a brand new math revolution taking off that appears certain to profoundly change much of what electronics is and what it will be able to do. All the noise is over *wavelet theory*, an incredibly powerful new technique that promises to blow the 200 year old *Fourier* analysis, synthesis, and transforms completely out of the water.

Why worry about some obtuse new math theory? Well, first because it is there. And second, because it is a sure fire winning topic for a school paper. And thirdly, there's a lot of electronic doors about to suddenly get slammed in your face if you do not *quickly* pick up on exactly what wavelet theory is and what it can do for you.

Fourier analysis is (er- better make that *was*) a method of giving you a second way of looking at and dealing

with electronic signals. Besides the intuitive or "real world" *time domain*, Fourier techniques let you create a separate *frequency domain*. Things not at all obvious in the time domain become quite clear in the frequency domain, and vice versa.

For instance, a square wave in the time domain is just a signal that keeps bouncing up and down between two levels. In the frequency domain, that same square wave can be shown to consist of an infinite string of sine-waves. Specifically, you can build up a square wave from its fundamental sinewave, one third its third harmonic, one fifth the fifth harmonic, and so on up the line.

A few of the zillions of places that the frequency domain can become important include spectrum analysis, holograms, video image compression, music synthesis, side looking radar, picture deblurring, biophysics, earthquake detection, neural computing, geophysical exploration, human aural and visual processing, HDTV channel squashing, pattern recognition, hard disk storage, nonlinear harmonics, speech generation, robotic sensing,

A New wave in applied mathematics

B. Cipra, *Science* 24 Aug 1990, pp 858-859.

New wave number crunching

C. Brown *E.E. Times*, 5 Nov 1990, pp 31-34

Video compression using 3D wavelet transforms.

A. Lewis, *Electronic Letters*, vol 26 no 6 pp 396-8.

Non-orthogonal wavelet representations in relaxation networks.

J. Daugman, *New Developments in Neural Computing*, pp 233-50.

A theory for multiresolution signal decomposition.

S. Mallat, *IEEE Transactions on Machine Intelligence*, v11-7 pp 674-93.

Wavelet transformation in signal detection.

F. Tuteur, *8th IFAC/IFORS Symposium*, vol 2 pp 1061-5.

Entropy reduction and decorrelation in visual coding.

J. Daugman, *IEEE Trans. Biomedical Engineering*, vol 36 no 1 pp 107-14.

Wavelet transformation in signal detection.

F. Tuteur, *ICASSP Speech Conference 88*, vol 3 pp 1435-8.

Complete discrete 2-D Gabor transforms.

J. Daugman, *IEEE Trans Acoustics & Speech*, vol 36 no 7 pp 1169-79.

Dispersive noise removal in t-x space.

Beresford-Smith, *Geophysics USA*, vol 53 no 3 pp 346-58.

Adaptive deconvolution by lattice filters.

S. Persoglia, *Bulletin of Geophysics Theory*, vol 27 no 107 pp 169-83.

A critique of seismic deconvolution methods.

A. Jurkevics, *Geophysics*, vol 49 no 12 pp 2109-16.

Statistical pulse compression.

E. Robinson, *IEEE Proceedings*, vol 72 no 10 pp 1276-89.

Fig. 5 – SOME KEY PAPERS on the new wavelet math theory which is now revolutionizing just about everything in electronics.

ELECTRIC MOTOR RESOURCES

Appliance

1110 Jorie Boulevard
Oak Brook, IL 60522
(708) 990-3484

Appliance Manufacturer

29100 Aurora #200
Solon, Ohio 44139
(216) 349-3060

Asea Brown Bovari

1460 Livingston Avenue
N. Brunswick, NJ 08902
(201) 932-6000

Bodine Electric

2500 West Bradley Place
Chicago, IL 60618
(800) 7BODINE

C&H Sales

PO Box 5356
Pasadena, CA 91117
(800) 325-9465

Design News

44 Cook Street
Denver, CO 80206
(303) 388-4511

Fair Radio Sales

PO Box 1105
Lima, OH 45802
(419) 227-6573

Fasco Industries

500 Chesterfield Ctr #200
St Louis, MO 63017
(314) 532-3505

Grainger

2738 Fulton Street
Chicago, IL 60612
(312) 638-0536

Herbach & Rademan

401 East Erie Avenue
Philadelphia, PA 19134
(215) 426-1700

IEEE/Energy Conversion

445 Hoes Lane
Piscataway, NJ 08855
(201) 981-0060

IEEE/Industrial Apps

445 Hoes Lane
Piscataway, NJ 08855
(201) 981-0060

JerryCo

601 Linden Place
Evanston, IL 60202
(708) 475-8440

Lindsay Publications

PO Box 538
Manteno, IL 60950
(815) 468-3668

Machine Design

1100 Superior Avenue
Cleveland, OH 44114
(216) 696-7000

Molon Motor & Coil

3737 Industrial Avenue
Rolling Meadows, IL 60008
(800) 52-MOTOR

Motion

Box 6430
Orange, CA 92613
(714) 974-0200

Northern

PO Box 1499
Burnsville, MN 55337
(800) 533-5545

PCIM

2472 Eastman Bldg 33-34
Ventura, CA 93003
(805) 650-7070

SAE

400 Commonwealth Drive
Warrendale, PA 15096
(412) 776-4970

electrocardiograms, outline detection, seismic profiling, correlation, and data compression.

In its spare time, Fourier analysis and synthesis leaps tall buildings in a single bound, milks cows, and even puts the cat out. The latest algorithms even sometimes may include a soft ice cream dispenser.

But the big problem with Fourier analysis is that everything was connected to everything else. Make even the slightest change, and you had to go back to square one and recompute everything. And while Fourier series is a great way to handle "most" of a square wave, it sure has troubles with the suddenly changing leading and trailing edges.

But many real world problems are like that. A mix of some stuff that is suddenly and dramatically changing, combined with other areas that are more or less stationary or otherwise uninteresting.

What wavelet theory does is let you selectively mix and match *wavelets*

that can both deal *locally* with sudden changes and *globally* with averages and backgrounds. You can thus selectively apply all your math power precisely where it will do you the most good. And do so with speeds and efficiencies that were totally unheard of with traditional Fourier analysis.

Figure five shows you a few of the newer key papers involving wavelet theory. Start out with the *Science* and *E.E. Times* overview summary stories before you get into the heavy stuff.

I've recently added a WAVELET.PAK program to my *GENIE* PSRT.

Let me know if you want to get into this any deeper.

New Tech Literature

The prices of bright red visible laser diodes are starting to drop bunches, with a \$45 in singles unit now being offered by *Haltek Electronics*. In the newer high visibility 630 nanometer wavelength. The same as helium neon, no less. Plan on \$5 visible lasers with-

in two years or so.

New data books for this month do include that *Special Purpose Linear Devices* entry from *National*. Be sure to check out their LMC835 digitally controlled graphics equalizer you'll find on page 1-227.

Three other new data books are the *Logic Databook* from the *Integrated Device Technology* folks, that new *Optoelectronics and Image Sensors* from *Texas Instruments*, and that new *Integrated Circuits Data Book #33B Supplement* from *Burr-Brown*.

Static memory RAM specs cleverly disguised as baseball trading cards are being offered by *SGS* in an unusual promotion. These are the same folks that previously gave you soup cans full of assorted free integrated circuits and soap boxes full of EPROMs.

Three interesting new surplus catalogs showed up in today's mail. They do include *Circuit Specialists*, *International Micro Electronics*, and *H&R Enterprises* publications.

Free samples this month include 1K Serial EEPROMs from *International CMOS Technology*, and SCOPE Octal drivers from *Texas Instruments*. TI also has a new three volume set on *Digital Signal Processing Using the TMS320* available.

Turning to my own products, for the fundamentals of digital integrated circuits, be sure to check into my classic *TTL* and *CMOS Cookbooks*. And, as you can tell from my nearby *Synergetics* ad, we've now got *Hardware Hacker III* and *Ask the Guru III* reprints available, as well as some new PostScript books by other authors.

Also, a reminder that I do have this great new PostScript PSRT roundtable and library up on *GENIE*. You'll also find lots of *Hardware Hacker* and all of the *Midnight Engineering* preprints and other resources here.

Finally, I do have a new and free mailer for you which includes dozens of insider hardware hacking secret resources. Write or call for info.

Our usual reminder here that most of the items mentioned appear either in the *Names and Numbers* appendix or in the *Motor Resources* sidebar.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8-5 in *Mountain Standard*

Time. Let's hear from you. ♦

Don Lancaster's

Hardware Hacker

April, 1991

Machine shop resources
Infrared people detection
Elegant simplicity contest
Liquid crystal battery tester
Exploiting paradigm shifts

This month's topics include finding new hackable project ideas, working with infrared people detectors, checking out those "in-package" battery testers, another contest, and a fresh look at machine shop resources.

Let's start off with some of the key secrets behind...

Stalking the Wild Paradigm

I've recently gone over dozens of my successful hardware hacking projects and hundreds of my failures over several decades, trying to fathom out what worked and what did not. I am convinced that one of the key underlying secrets is watching for and then profiting from *paradigm shifts*.

A *paradigm* is just the way people perceive things to be. Any *paradigm shift* occurs whenever someone upsets the apple cart. Which could happen whenever any vastly new or different way of doing things becomes obvious. Or something becomes much cheaper or more widely available.

In general, hardware hacking does not do well in the "business as usual" times. It is only when some sudden and dramatic change or another fundamental shift in values takes place that new opportunities emerge.

Some ancient personal examples of paradigm shifts: The low cost silicon controlled rectifiers which blew the thyatron out of the saddle and opened up psychedelic lighting. Triacs that made light dimmers and power tool speed controls possible. RTL digital integrated circuits that revolutionized counting and digital logic.

Cheap nickel-a-bit shift registers and character generators that permitted my *TV Typewriter* (RE Sept 73) the opening round fired in the personal computer revolution. Simple active filters developed by theoretical types totally unable to communicate either coherently or intelligently.

Price reductions in CMOS chips. The 6502. The KIM-1 microcomputer. De-mathifying those pseudorandom sequence generators. The Apple IIe. The monumental new stupidities now

hopelessly crippling all of traditional publishing. CD ROM. That insanely great PostScript language.

Your key hacker opportunity: *The people who are doing the shifting of the paradigm usually do not have the slightest idea what they are doing, since they will be always rearwardly focusing on the way things were.*

When a paradigm shifts, all sorts of new hardware hacking opportunities immediately open up. Especially if you are able to view reality from a different perspective. Or can reduce the cost of something by 50:1, totally changing the market to something totally foreign (and totally misunderstood) by the way things were.

If there has not been any recent paradigm shift, the chances are it will be tricky to come up with a useful product. For instance, there has not been one iota of improvement in any of those *Peltier* thermoelectric cooling modules in the past two decades, owing to the inherently low efficiency of these devices. Any hacking work done the "old way" here is probably a

total waste of time.

Similarly, if useful computer touch screens would ever have done anything, these should have taken off years ago. Your bottom line is that people do not like to touch computer screens, and trying to convince them otherwise is probably fruitless. The same goes for *Dvorak* or other "improved" keyboards.

The whole point of this Hardware Hacker series is to try and identify those paradigm shifts that you can work with and profit from. We have seen many recent examples.

These include anything and everything involving PostScript, magnetic refrigeration, wavelet theory, desktop finishing, visible laser diodes, direct toner printed circuits, and book-on-demand publishing. To name just a few random samples.

For some others, see my *Eminently Hackable Emerging Technologies* story found in that July-August 1990 *Midnight Engineering*. And downloadable as my *GENIE* PSRT file #116 EMERGOP.TXT.

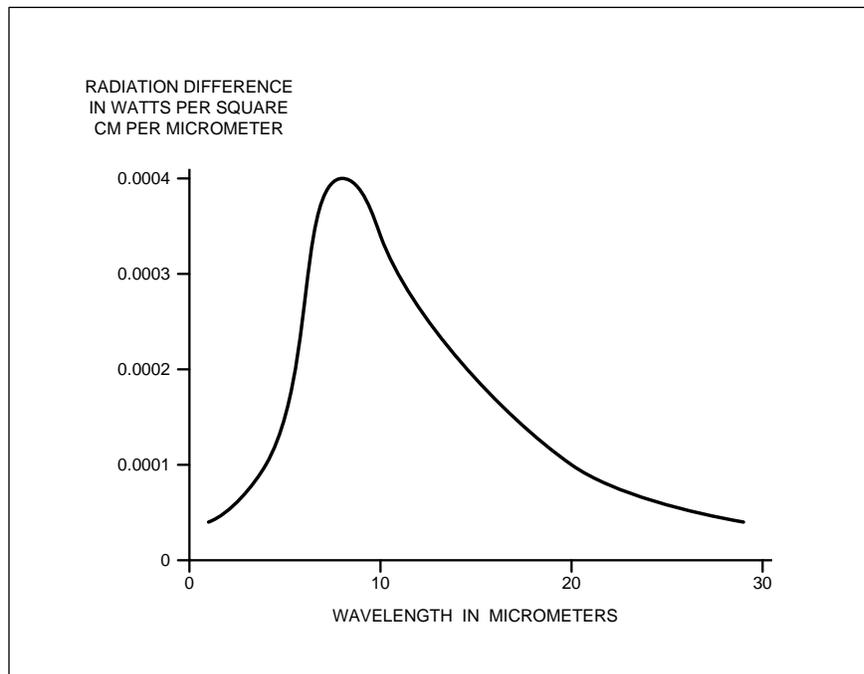


Fig. 1 – THE FAR INFRARED SIGNATURE of a 98 degree F person in a 70 degree room environment. Note that these are extremely weak power levels.

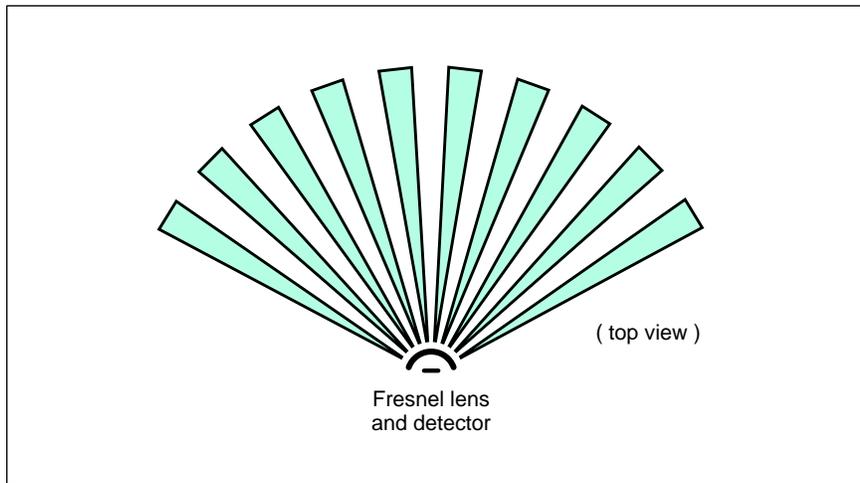


Fig. 2 – SINCE PRYOELECTRIC INFRARED SENSORS are capacitors, they cannot hold a dc or stationary level. To emphasize changes in motion, special Fresnel lenses are often used that have "hot" and "cold" areas as shown here.

The opposite side of the paradigm shift is the *sucker bet*. Any thoroughly plowed ground that, for one reason or another, just did not and will not ever hack it. Ratholes into which countless corporate dollars have been foolishly dumped with zero visible results. Or results having the exact opposite of the intended effect. Obvious sucker bets include the UNIX language, the *NeXT* computer, *TrueType*, or most anything involving *Teletext*.

Infrared People Detectors

Street prices on the infrared people detectors are dropping very fast, so now is a good time to review how these electronic devices work. Several important uses now include burgular alarms and occupancy sensors.

Any object not at absolute zero will radiate heat. At lower temperatures, a *black body radiation* pattern will usually be produced.

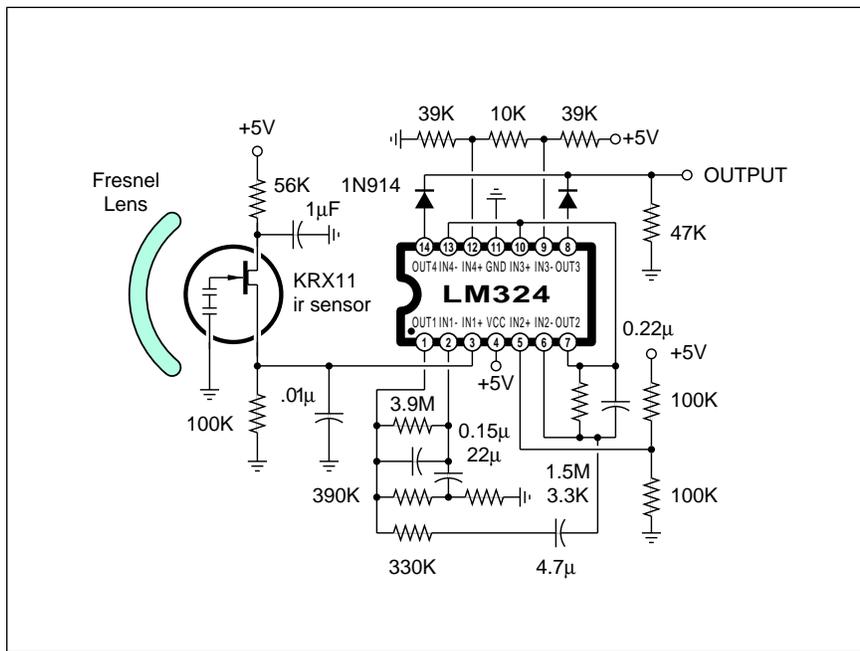


Fig. 3 – A "PEOPLE DETECTOR" intended for use as an office lighting control. The output goes high on any motion detection that would increase or decrease the input far infrared signature.

A human will normally radiate at 98 degrees Fahrenheit, compared to the other objects in the room which will typically radiate at a 70 degree range. A human body is a very weak radiator which becomes even more so when compared against the ambient.

Figure one is a typical curve of human body radiation in a normal room. As you can see, the radiated energy is centered on the eight micrometer range in the far infrared.

One sensor which is capable of detecting the radiation from a person is known as a *pyroelectric infrared detector*. These are available at very low cost from the *Amperex* division of *Phillips*, among others. As we'll see shortly, Amperex has lots of good ap notes and data sheets available.

The pyroelectric infrared detector consists of one or two detectors that in turn input to a field effect transistor source follower.

The basic detector is a capacitor, across which several hundred microvolts of dc voltage will be generated in the presence of a warm and non-moving human body. The detectors are often used in side-by-side differential pairs that are imaged slightly differently. They will tend to cancel out stationary sources.

One very big gotcha here: These sensors are basically a capacitor so they cannot indefinitely produce a dc output voltage. Even the tiny bias current of a field effect transistor's gate is enough to flatten any long term dc level. Thus, the pyroelectric infrared detector only is able to respond to *changing* levels of infrared energy. Stationary sources are ignored.

So, the trick is to make the infrared signals appear to be rapidly changing. One obvious way is to have the person run through the beam. This can produce a usable transient. But something better is clearly needed.

The traditional method was to chop the beam by putting a bladed fan in front of it. This would input an infrared square wave that represents the difference between the body and fan blade temperatures. By knowing how fast those blades whipped past, you could also do a *synchronous demodulation* that could also increase your detection sensitivity.

But moving fan blades and synchronous detectors are expensive.

Somehow you have to gather your infrared energy from your area and concentrate it on the detector surface. Although mirrors are one solution, a plastic *Fresnel lens* is both a better and more economic one.

Fresnel is pronounced "Fra-nell"

Now for the tricky part. Instead of making the lens operate uniformly over the surveyed area, it is purposely striped so that there are "strong" and "weak" sensing areas. A typical lens pattern is shown in figure two.

As the person walks through the beam or otherwise moves, they travel between the strong and weak lens areas, creating more of a varying signal than they would otherwise.

Figure three shows you a schematic of a simple people detector using a dual element pyroelectric detector and a quad op amp. The Fresnel lens has strong and weak areas that alter the strength of the infrared signature of a moving person. This is sensed by the detector and routed to a x600 ac amplifier. The combined frequency response of the detector and the amplifier is an 0.3 to 5 Hertz range. Which is usually an optimum for most people movements.

The output of your amplifier is routed to a *window detector* or dual comparator. This detector will output a signal on any sudden change in the infrared signature.

Usually, the output of the window detector is routed to a counter of some sort to minimize false alarms.

In security applications, an alarm output is created. For the occupancy detectors, the lights are quickly turned on, and then left on for a selected number of minutes. A fifteen minute delay is often an optimum for people who are usually sitting at a desk or bench. Each time they move, the on time gets extended.

One commercial source of ready-to-go occupancy sensors is *Leviton*. These fit in an ordinary power outlet. Occupancy sensors can dramatically reduce the power bills in most larger commercial buildings.

Another alternative to pyroelectric detectors is the *Kynar Piezo Film* from the *Atochem* folks. While less sensitive to infrared and much more tuned in to motion or vibration, this approach can let you integrate your lens and sensor into one single thin

assembly. Penwalt also does have ap notes and data sheets available.

While the electronics involved in people detection are both simple and straightforward, your mirror or lens design is not. Thus, you are better off using some already developed and debugged commercial lens/detector combination than trying to work one up from scratch.

Figure four lists some of the more readable *Amperex* ap-notes and data sheets on people detecting. This is a very good starting point for picking up all the infrared sensing basics.

UPDATE: Shortly after this story was run, *Amperex* discontinued all infrared detector work, and their fine ap-notes are no longer available. The reason was that the new *Kynar piezo* sensors by *Penwalt/Atochem* were far simpler and cheaper to use.

Because of the new California law mandating these sensors in all new office building constructions, infrared people detectors have become a low cost commodity, readily available at any electrical wholesale supply.

Both *Herbach and Rademan* and *Heath* offer ready to go units for far less than the cost of building them up yourself. Especially when you factor in the tricky Fresnel lens design.

Typical surplus pricing is in the \$12 range. A great buy.

Those New Battery Testers

As all of you long time Hardware Hackers know, I am very much a fan of *elegant simplicity*, or any way to do very much with very little.

Those *Duracell* folks have finally reduced battery testing to an elegantly simplistic minimum. Just in case you haven't noticed, there's now a free battery tester built into their battery packaging. An incredibly sophisticated one. And obviously cheap.

Flashlight cells do not often fail suddenly. Instead, because of cell polarization and other effects, their internal resistance slowly increases.

This in turn drops the cell's voltage under load, eventually to the point where they can no longer be used.

To test a flashlight cell, just place a power resistor across it that represents a fairly heavy load for that size cell. Wait several seconds. Then measure that cell's open circuit voltage.

In the *Duracell* package, there is a pair of printed contacts with a printed power resistor between them. Around three ohms for the AA size alkaline cell. The resistor gets noticeably hot when you connect your cell to it.

Now for that elegantly simplistic part. As figure five shows us, their printed resistor is not uniform. Instead it forms a *wedge* shape. The narrow

Pyroelectric infrared detectors for movement sensing.

Technical publication #134, 1984

Remote level sensing using pyroelectric infrared detectors.

Technical publication #135, 1980

Low cost remote sensing radiometer using the RPY89 infrared detector.

Technical publication #138, 1980

Low cost automatic light switching using passive infrared sensors.

Technical publication #147 February 1985

Ceramic pyroelectric infrared sensors and their applications.

Technical publication #163

Passive infrared (PIR) intruder alarms.

Technical publication #213 April 1986

Movement sensing using a multi-element fresnel lens.

Amperex ap note, November 1988.

KRX10 dual element pyroelectric infrared sensor.

Data sheet, September 1988.

KRX11 dual element pyroelectric infrared sensor.

Data sheet, September 1988

RPW100 dual element pyroelectric infrared sensor.

Data sheet, September 1988

Fresnel lens data sheet and explanatory notes.

Phillips data sheet, April 1986

Fig. 4 – AMPEREX ap notes and data sheets on pyroelectric infrared detectors.

portion of the wedge at the bottom will offer you a higher resistance *per unit length* and thus will get *hotter* than the upper and wider part.

Thus, this particular resistor will set up a temperature gradient that ends up hottest at the bottom and coolest at the very top.

How hot? Well, that all depends on how much current your cell puts out under load. Power equals the current squared times the total resistance.

A thin liquid crystal coating gets placed on the reverse side of the resistor. This is the same stuff used in clinical and desk thermometers. At a certain *transition temperature*, your liquid crystal will turn a bright green. Below that temperature it will remain black, and above it a dark grey.

The more the available current under load, the higher the green spot on the display. Thus, a "good" cell will have a "high" green spot, and a "bad" cell might have a "low" green spot, or perhaps none at all.

The results surely change with the ambient temperature and the size of the cell being tested, but they assume you are testing your cells at room temperature, and that the cell being tested is the type and size provided in the package.

So, basically what you have here is a three cent 0 to 500 DC milliammeter. Done elegantly and simply.

Which other uses can you come up with for this new concept? Or, better, yet, let's have us an ...

Elegant Simplicity Contest

What else is elegantly simple? For sure the P-38 can opener, which I rank as far and away the most outstanding invention of the twentieth century, bar none. Such frivolities as automobiles, television, computers, aircraft, and even Hostess Twinkies should pale by comparison.

Especially when you do factor in bang-for-the-buck, reliability, first costs, complexity, and the end user performance.

For this month's contest, just tell me about something in the P-38 can opener class that really needs further developing. We'll have a dozen or so *Incredible Secret Money Machine II* book prizes, along with an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the best of all.

To get you started thinking about elegant simplicity, here are several ideas: We need a sleeping bag zipper with a "snowplow" snoot on it which does not jam itself on your pulled-in material at 4 am. We do need a boot shoelace that works, especially for oddball lengths. Sorely needed are a line of gourmet truth-in-advertising foods. Such as cream of mushroom soup with mushrooms, or pork and beans with pork. And Detroit is at long last wiseing up to the fact that putting a plain old pin through the differential dramatically improves the handling in mud or snow.

Finally, it goes without saying that

we just gotta have a stainless steel potato chip, since the real ones break on the third or fourth time into the dip. Yes, you could use a P-38, but...

Let's have your thoughts on elegant simplicity, electronic or otherwise. As usual, be certain to send all of your written entries directly to me here at *Synergetics*, rather than on over to **Radio-Electronics** editorial.

Machine Shop Resources

What does a hardware hacker really need in the way of purely mechanical "machine shop" stuff? Obviously, this depends on where you live and what you are up to. But it is super easy to pour scads of time and dollars into overpriced machinery that you never use and that will never pay for itself. Either in income or pleasure returned.

I live in a remote rural area, so I guess I've picked up more than I'd recommend in the way of shop tools. I do have a medium sized drill press which still is precise enough and fast enough to drill a #67 hole in a printed circuit board. I've added a rotary X-Y table to this for light milling.

There is a smallish *Kepro* printed circuit board shear, and my *Roper-Whitney* hand punch. A decent vise for sure. A hand moto-tool. Also a largely unused *Atlas* four inch lathe and the essential grinder to feed it. And finally a table mounted router.

The first thing you should do is look around your neighborhood and find out just what *nonobvious* mechanical resources are available to you. Is there a retired machinist down your street with a full home shop and nothing to do? A community college with open-ended shop courses? Or some firms with excess capacity?

Locally, there is this trailer hitch works which has a giant shear and brake. They can instantly and cheaply cut ten gauge steel, usually from free scrap off the floor. Other locals I've gladly used include an air conditioning shop, a ranch machinery repair service, a solar products factory, and a heavy machinery rebuilder/trader.

In our resource sidebar for this month, I've tried to gather together a few important hacker machine shop resources. By far the most important two of these are *Small Parts*, which stock everything your hardware store never heard of and custom cut metal

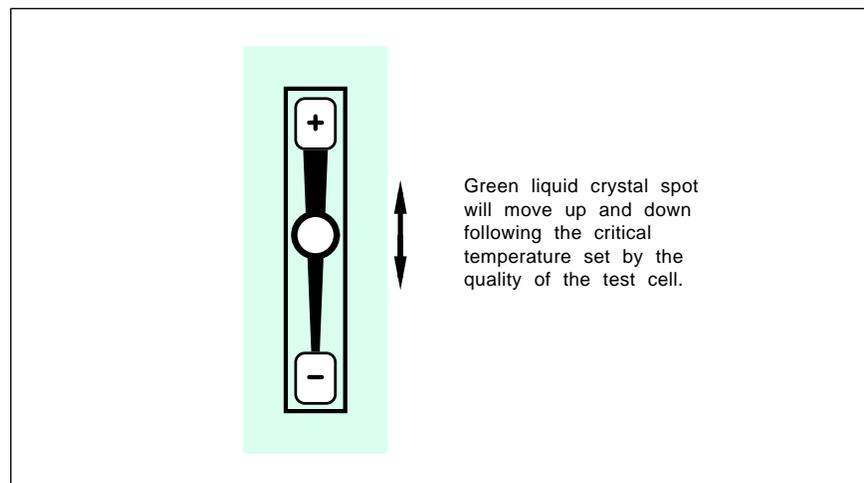


Fig. 5 – THE LOAD RESISTOR in the Duracell battery tester is wedge shaped so that it gets hotter per unit length at the bottom than at the top. A liquid crystal coating changes color at a critical temperature, moving a green indicating spot up with a strong cell and down with a weak one.

and plastic for you in tiny quantities; and *Lindsay Publications*, who have a mind boggling array of lower priced machine shop books in stock.

One old line "stocks everything" distributor is *McMaster Carr*. See if you can't cop one of their humongous 3000 page catalogs. Others include *Enco*, *KBC Tools*, *J & L Industrial Supply*, *Rutland*, and *Wholesale Tool*. And, of course, *Sears*.

Two useful surplus sources include *Bordens* and *C & H Sales*.

My favorite two mechanical trade mags are *Design News* and *Machine Design*. The zillions of others include *American Machinist*, the *Used Equipment Directory*, and *Metfax*.

There is also a huge collection of oversize "throwaway" shoppers that include *New Equipment Digest* (great free product samples!), *Industrial Product Bulletin*, *Industrial Equipment News*, and *Metalworking Digest*.

On the hobby side of the fence, the *Model Railroader* obviously belongs on this list. Two others include *Home Shop Machinist* and *Modeltec*.

Once again, we've got a rather long list here, but I do have this hollow feeling I've missed something major.

For our second contest this month, just tell me about any hacker useful machine shop resource that I don't already know about.

As we've seen time and time again, the industry trade journals can be an incredibly cost effective information gateway which no hacker could do without. See *Uhlricht's Periodicals Dictionary* at your local library for a complete listing.

New Tech Literature

There is a great *Telecom Design Solutions* manual from *Teltone* this month on such neat goodies as call progress detectors and DTMF chips. Included are some great ap notes. And from *Phillips/Signetics*, a brand new data handbook on *Programmable Logic Devices* for your custom work.

From *Newark Electronics*, the new 1300 page *Catalog #111* on everything electronic they distribute.

New trade journals for this month include *Circuits Assembly* on printed circuit boards and *Motion Control* on robotic power controls. Newsletters include *Robotics Now* and the *NSRA News*. The latter is from the *National*

MACHINE SHOP RESOURCES

American Machinist 826 Broadway, 4th Floor New York, NY 10003 (212) 477-6420	J&L Industrial Supply 31800 Industrial Drive Livonia, MI 48150 (800) 521-9520	Model Railroader 21027 Crossroad Circle Waukesha, WI 53187 (414) 272-2060
Bordens Surplus Center 1015 West O Street Lincoln, NE 68501 (800) 228-3407	KBC Tools 6300 18-Mile Road Sterling Heights, MI 48314 (800) 521-1740	Modeltec Box 286 Cadillac, MI 49601 (616) 775-6296
C&H Sales PO Box 5356 Pasadena, CA 91117 (800) 325-9465	Kepro 630 Axminister Drive Fenton, MO 63026 (314) 343-1630	New Equipment Digest 1100 Superior Avenue Cleveland, OH 44114 (216) 696-7000
Design News 44 Cook Street, Suite 210 Denver, CO 80206 (303) 388-4511	Lindsay Publications PO Box 583 Manteno, IL 60950 (815) 468-3668	Roper-Whitney 2833 Huffman Blvd Rockford, IL 61103 (815) 962-3011
Enco 5000 West Bloomingdale Chicago, IL 60639 (800) 621-4148	Machine Design 1100 Superior Avenue Cleveland, OH 44114 (216) 696-7000	Rutland PO Box 587 LaPuente, CA 91747 (800) 289-4787
Home Shop Machinist 2779 Aero Park Drive Traverse City, MI 49684 (800) 447-7367	McMaster-Carr Box 54960 Los Angeles, CA 90054 (213) 692-5911	Small Parts PO Box 381966 Miami, FL 33238 (305) 751-0856
Industrial Equipt News Five Penn Plaza, 8th Floor New York, NY 10001 (212) 629-1500	Metalworking Digest 310 Gibraltar Drive Morris Plains, NJ 07950 (201) 292-5100	Used Equipment Dir. 601 Pavonia Avenue Jersey City, NJ 07306 (800) 526-6052
Industrial Prod Bulletin PO Box 650 Morris Plains, NJ 07950 (201) 292-5100	Metfax 29100 Aurora Road #200 Solon, OH 44139 (216) 248-1125	Wholesale Tool 12155 Stephens Warren, MI 48090 (800) 521-3420

Service Robot Association.

Burr Brown has just introduced an applications and product info BBS at (602) 741-3978.

In our free samples department, *Exel* has borrowed a marketing ploy from the magazine clearing houses - a series of stamps. Pick any three on the return card for free samples of their non-volatile memory products. And *Annulus* has free samples of their 8PDT switches which are great for switching serial ports or any EPROM chips into or out of circuit.

For mechanical stuff, the definitive books and videos on glass etching are available through *Professional Glass Consultants*.

Turning to my own products, for the essentials of making your hardware hacking profitable, do check out my *Incredible Secret Money Machine*. I

have also just released the *Hardware Hacker III* and *Midnight Engineering* book-on-demand published reprints.

I do have this great new PostScript PSRT roundtable and library up on *GENie*. You'll also find lots of *Hardware Hacker* and all of the *Midnight Engineering* preprints here.

Finally, I do have a new and free mailer for you which includes dozens of insider hardware hacking secrets.

Our usual reminder here that most of the items mentioned appear either in the *Names and Numbers* appendix or in that *Machine Shop Resources* sidebar shown above.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8-5 in *Mountain Standard Time*. Let's hear from you. ♦

Don Lancaster's Hardware Hacker

May, 1991

Reloading toner cartridges
New electronic phone book
More Santa Claus machines
Secret laser printer manuals
VHF & microwave resources

Every now and then, it seems a good idea to go back over some of our older *Hardware Hacker* subjects and bring them up to date. Certainly one of the most popular topics ever found on our helpline involves...

Toner Cartridge Reloading

PostScript laser printers are fast becoming a major industry. There are many millions of units now in use. By far the best and the most popular versions will use several styles of laser engines OEM built by *Canon*. These engines were originally intended to accept a throwaway plug-in cartridge. Inside the cartridge is a source bin of toner, a photosensitive drum, and a spent toner holding tank.

Played according to the rules, you can buy these cartridges for \$120, use them for 4000 copies and end up with a per-page toner cost of three cents.

As we have seen before, you can easily reload these cartridges yourself dozens of times. Today, you can do so in two minutes for a cost of \$5.50 or less, and can easily reduce your per page toner costs to 0.2 cents per page, a 15:1 cost improvement.

Besides saving big bucks on your own printer, you could also resell recharged cartridges for as much as \$15 or even \$19 each, done as part of an ongoing neighborhood service.

There's lots of exciting new things happening in the toner recharging industry, so I thought we might pick up some fundamentals and then bring you up to date on the newest and the best insider secrets.

What is toner? Well, it is a mixture of (usually) black stuff and hot glue. Specifically, toner is a fine powder which has very precisely controlled magnetic, electrostatic, thermal, and visual properties. Most toners are basically a mixture of ferric oxides, polyethelene, and lubricants.

Toner starts out in the cartridge's *fresh toner tank*. A magnetized roller then picks up a very uniform layer of toner. Meanwhile, a nearby photosensitive drum gets flooded with light

and then electrostatically charged. It next gets selectively discharged by a laser beam, leaving a charge pattern on the drum. As the drum rotates, it passes very near the magnetic roller and the toner selectively jumps onto the drum, sticking by electrostatic forces only where you want an image.

As your drum rotates further, it passes very close to a highly charged piece of paper, and the toner particles then jump over onto the paper. Any remaining toner that was left on the drum gets scraped off and routed to a *spent toner holding tank*. The photosensitive drum then continues on its way for another cycle.

Meanwhile, you now have your image on the paper. But it is only held there by gravity and by rather weak electrostatic forces. This will easily smear if you touch it. The paper then goes on to a *fusion roller* assembly. Heat and pressure will melt the toner and force it into the paper, giving you a fairly durable final hard copy.

One very important part of most fuser assemblies is the *wiper pad*. The wiper pad has a small quantity of silicon oil in it that both lubricates and cleans up any remaining toner on the pressure rollers. Your wiper pads are

usually replaced whenever a cartridge is recharged. Note that just washing a wiper pad is a no-no.

Our first rule: Toners vary from machine to machine. Typical *Canon* laser printers use what is known as a *black write* system, since laser diodes will last much longer this way. On the other hand, all but the newest and most expensive copiers use a *white write* system so that light ends up as white and dark as black.

Thus: *Copier and Laser Printing toners must NEVER be interchanged or substituted for each other!* There are usually mechanical interlocks that prevent you from plugging a copier cartridge into a laser printer and vice versa. If you attempt to defeat these interlocks, you will end up using the wrong toner. At the least, this gives you useless copies, and at worst, this can cause serious damage.

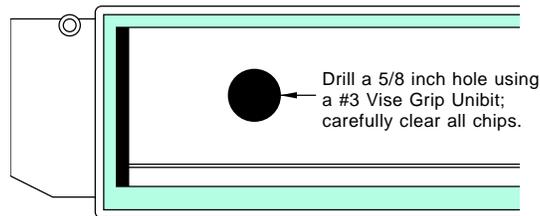
Similarly, toner chemistry changes from printer to printer. Most especially between manufacturers. Our second rule: *The refill toner you use must be pretested in and rated for the exact cartridge you are refilling.*

So where do you get refill toner and all those wiper pads? My two favorite sources are *Don Thompson* and *Lazer*

HP MANUAL	HP PRINTER	APPLE PRINTER	QMS PRINTER
02686-90920 (CX Engine)	LaserJet I	LaserWriter LaserWriter Plus	PS800
33449-90906 (SX Engine)	LaserJet II LaserJet III	LaserWriter NT LaserWriter NTX	PS810 & Turbo PS820 & Turbo
33459-90906 (SX Engine)	LaserJet IID LaserJet IIID	-----	-----
33471-90904 (LX Engine)	LaserJet IIP	Personal LW NT	PS410

Fig. 1 – HERE'S A LIST of all the most popular *PostScript* laser printers, their equivalent service manuals, and the style of toner cartridges they use.

To refill an older CX cartridge with the punch-and-go method, you first snap off the cardboard label and then drill a toner filling hole...



A second CX hole is needed to let you empty out your spent toner holding tank. This area is found underneath the cartridge...

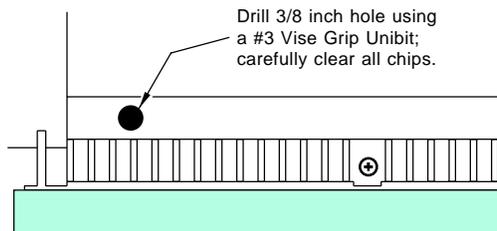


Fig. 2 – THE CX CARTRIDGE is easily recognized by its large drum and its obvious "lunchbox" handle. Here are my "punch and go" refilling secrets.

Products. There is yet another outfit known as *Black Lightning* that stocks specialty toners for T-shirt and fabric printing uses.

The toner industry has its own trade journal. It is called *Recharger*, and is chock full of supplier ads and useful industry info. There are also at least a dozen recharging associations who do have lots of seminars and conventions. Details on all of these usually appear in *Recharger* magazine.

The great news today in toner refilling involves new third party hard coated drums. For some reason or another, the factory stock drums are made needlessly soft. The third party drums instead are ultra hard and can easily be used for dozens of reloads. One leading importer of hard drums is *CopyMate Products*.

Let's look at some specific refilling details. Certainly the most popular cartridges are those used in the *Canon CX, SX, and LX* engines. Figure one lists many popular laser printers and

the specific engine used in each one. This figure also reveals to you the outstanding *Hewlett-Packard* repair and service manuals involved. These manuals, and all major parts can be had overnight via VISA/800.

For some reason which I simply cannot fathom, *Apple Computer* absolutely insists that you use the HP service manuals to keep your Apple LaserWriter printers alive. As near as I can tell, this is some sort of a top secret rebate policy.

At any rate, you can recognize the older CX cartridges by their larger three inch drums, their red-yellow-green end dial, and the obvious big lunchbox handle. While the original LaserWriter and all similar printers using these are rather dated, they do remain very useful, especially when printing lots of heavier stock. Many used bargains are now cropping up involving these older machines. Two sources are *Don Thompson* and *The Printer Works*.

Non-PostScript laser printers, of course, are an utterly useless ripoff, so be absolutely certain that your used machine can speak genuine Adobe PostScript.

Before we begin, note that the photosensitive drums must *never* be exposed to strong light, or to *any* light at all over any long period of time. Never get fingerprints on the drum. Cotton gloves are a good idea.

Toner is an ultra fine powder that can end up all over everything. It is sometimes best to work outside, and possibly wearing a mask. Toner can, in theory, explode a vacuum cleaner, but this rarely will happen. But do be careful, just in case.

The general steps in refilling any cartridge are fivefold:

- (1) Remove and discard any waste toner from the spent toner holding tank. Do not reuse this toner;
- (2) Refill your fresh toner supply tank with a new bottle;
- (3) Lubricate the drum with a light dusting of *Pixie Dust* (see below);
- (4) Replace the oiled wiper felt on the fusion assembly elsewhere in the printer; and finally...
- (5) Update accurate life and service records on a suitable label.

Figure two shows you those CX refilling details. There is really never any reason to tear down a CX cartridge, except to substitute a hard drum. The original factory drums are big enough that you can often get four or five refills as is. For most people most of the time, a total teardown will cause many more problems than it will solve. Remember that your ultimate goal should be minimizing all of your per-page toner costs, not maximizing the number of recharges for each drum. An extra recharge is pointless if it costs the end user more per page to do so in the long run.

If you absolutely have your heart set on taking any CX cartridge apart, you'll need two special tools. One is a special tamperproof *Torx* bit. This is *EVCO* part number #945B700 and is available from *Jensen Tools* as well as most refilling supply houses. The second is a special pin-pulling tool called a *CX Glompenstractor* and is available once again by way of *Don Thompson*.

Should you use my *punch and go*

method, you will have to drill two holes in the cartridge on your first reload. Which is best done using a rather unusual step-drill called a #3 *Vise Grip Unibit*. These are available from *Jensen Tools* or from any larger electrical contracting supply house. When used with a variable speed hand drill, the Unibit should cleanly cut a perfectly round hole in brittle plastic, while producing a single and easily grabbed chip.

After drilling the holes, the spent toner is shaken or vacuumed out. You could reseal this hole with plain old Scotch Tape (be VERY careful to get a secure seal!), or else you use a nickel *Caplug*. Your fresh toner bin hole gets similarly used to accept a bottle of new toner and then resealed.

Figure three shows you the SX cartridge recharging. The LaserWriter NTX is a typical machine that uses this cartridge. The SX cartridges have a one inch drum and end up rather flat looking, being much wider than thick. Should you decide to tear down the cartridge or upgrade to a hard drum, a different glompenstractor is needed having a narrower snout.

The details of my punch-and-go refill method remain pretty much the same. First time around, you drill a suitable filling and emptying hole. Once again, the #3 *Vise-Grip* Unibit in a variable speed hand drill is ideal for this. To refill, drain and discard the spent toner and reseal. Then fill the fresh toner tank and reseal.

Figure four shows you the newest LX cartridge recharging. The personal laser printers, such as the new *QMS PS-410*, do use this cartridge. The LX cartridge is recognized by its small size, an obvious spring and its "white trim" gears and bearings.

No holes are required. To access the toner bin, pull the two pins by using *ChannelLock #357* end pliers. The tank can then be refilled through the existing *Caplug*. To change the drum or drain the spent toner, remove the four *Phillips* screws on those nylon drum bearings and then pull the drum. Spent toner can be simply vacuumed or shaken out.

After a recharge, it is a good idea to *very lightly* dust any drum with a suitable lubricant. Many of these are based on plain old zinc stearate. Only don't substitute baby powder since the

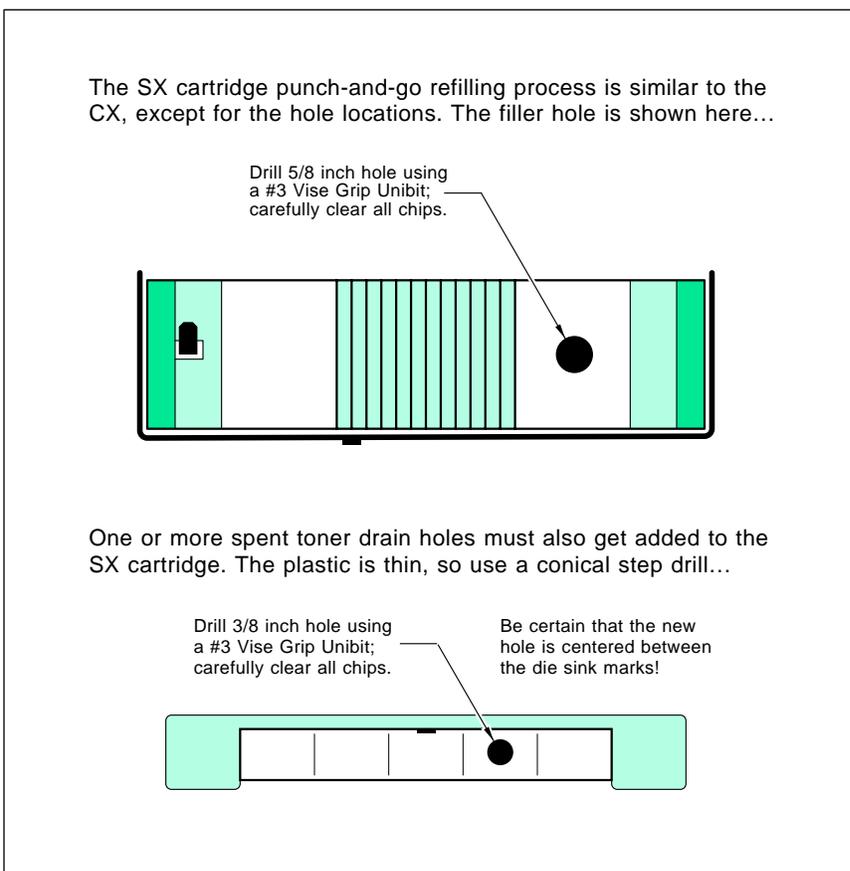


Fig. 3 – THE SX CARTRIDGE is wider than it is high, has a small drum, and is the most popular cartridge for the larger 8 PPM PostScript laser printers.

perfume and oils will do you in. The usual name here is *Pixie Dust*. Pixie dust is available through most of the recharging supply houses at very low cost. You can make a "duster" from the toe of a child's athletic sock and a rubber band.

Once again, the wiper pad on the fusion assembly should get replaced every time you change the cartridge. You normally keep your old wiper wand and drop a new peel-and-stick oiled nomex felt strip in place.

While you can obtain toner tank resealing strips, travel of any kind is extremely rough on toner cartridges. I do not recommend ever moving a cartridge further than you can gently and personally hand carry it. Nor do I recommend ever swapping your own cartridges for unknown outsiders. I strictly limit my personal recycling service to a six mile radius. Yours also should be. Pizza style service.

Reuse of toner removed from spent toner holding tanks is not in the least

recommended, nor is recycling your own wiper pads.

There does remain plenty of "zoo" aspects to the toner recycling. Certain irresponsible manufacturers have now begun some high profile national "recycling" programs which in fact destroys the cartridges rather than recycling them. The hope here is to permanently get the cartridges out of circulation before they could be refilled and reused.

Only an absolute idiot would participate in any program of this sort.

If you do nothing else, you can sell your empty cartridges locally for \$5 to \$10 each, and then contribute as much of the proceeds as you care to to your favorite environmental group.

Any salesman that tells you that normal use of any properly recycled cartridge can automatically void your printer warranty is telling you an outright lie for which they could be criminally prosecuted. Some others are literally gold plating stuff that does

Hardware Hacker

not in the least need gold plated. Yet others will substitute shoe polish for proper hard drum recoating.

Those recharge/repair schools run the gamut from outstanding and high quality bargains on down to outright ripoffs. To tell one from another, ask the school for a list of all the previous students in your area. Then call one or two of them.

You will have to pay *very* careful attention to details. But the new toner recharging industry is fast maturing and now offers all sorts of exciting and cost-saving new hardware hacking opportunities.

A Great Telephone Book

I'm often asked how I can usually find helpline names and numbers so fast. Well, I have built up my own resource data base over the years, and that is where I will often look first. Physically, this is just a big black notebook with lots of stuff that keeps falling out of it. Most of this data base appears in all of my *Hardware Hacker* reprints, and a downloadable and fully annotated selection of the best of the very best appears in my *GENIE* PSRT library as file #80 MYFAVOR.TXT.

But the number two place I always go to is the *Electronic Industry Telephone Book* from *Harris Publishing*. Although it lists for around \$50 per year, sometimes you can get a free or promo copy from a sales rep.

This national coverage gem works just like any other phone book, with alphabetical white pages and by-topic yellow classifieds. Their listings are very thorough, and I am continually amazed how often this one volume can solve so many problems.

Santa Claus Again

Several times now, we've taken a look at the new Santa Claus machines that create instant desktop prototypes at a tiny fraction of the time and cost of traditional methods. As we have seen, all the stuff out there so far is primitive, klutzy, and horrendously priced. At least so far.

We've also seen some outstanding new hacker opportunities here, that range from low cost desktop prototyping alternatives to offering up your own prototyping service bureaus by using the commercial systems.

While the best possible desktop prototyping solution remains "none of

the above", let's look at a pair of new alternatives.

Have you ever played around with your glue gun? While not too readily available, you can get polyethelene rods to use as glue sticks. This gives you a method for encapsulating components in high quality plastic or making your own custom connectors. Or of doing plastic casting at a tiny fraction of the usual mold costs.

Let's carry this one step further per the crude system of figure five.

Say you wanted to produce some large display letters in various styles and sizes. Just take a modified glue gun on a linear stepper and a no-stick base on a second linear stepper, and you should be able to put a plastic bead down that follows the shape of the letter. Repeat the process until the entire letter is created. The host computer traces out the proper path to build up the letter one bead at a time.

Admittedly, this is a rather crude system which is limited to thin two dimensional objects. And we haven't properly addressed the third dimension at all. But it is a good starting point that could lead to some exciting new developments.

One suitable stepper would be the *Hurst* model SLS. I've been meaning to work up some more details on this and on *Hurst's* new EPC-015 controller. Maybe in a future column.

There is a commercial variation of the "use a glue gun" desktop prototyping method. This is the brand new *Stratasys 3-D Modeler*. They refer to their process as a *Fused Deposition Modeling*, or FDM.

The system starts with a large roll of .020 or .050 diameter plastic or wax filament. The filament is heated just hot enough to make its outside tacky. The filament is then laid down into an existing pattern in the same way you can do artsy-craftsy stuff with string soaked in glue.

A three dimensional object is then built up, literally one string at a time. While they have an elaborate CAD software system based upon NURBS splines, the *PostScript* language and any old word processor should be able to do a vastly better job far faster and much cheaper.

The FDM method seems especially well suited for modeling containers and other hollow packaging products.

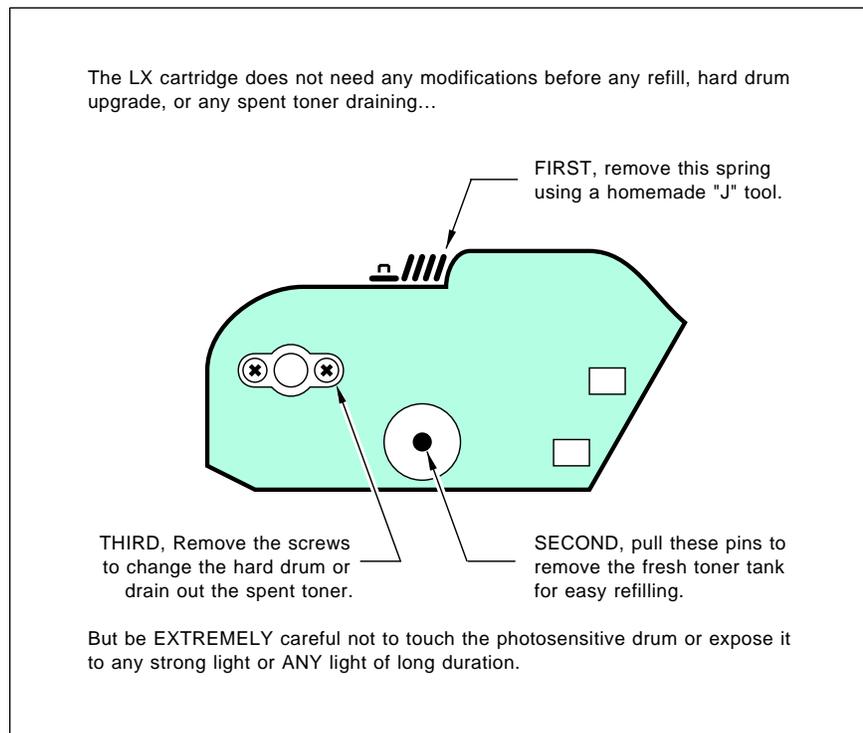


Fig. 4 – THE SMALLER LX CARTRIDGE is used in the "personal" 4 PPM printers and is easily spotted by its obvious spring and the "white trim". NEVER use copier toner in a laser printer!

But sharp edges appear tricky to do, especially gear teeth. Ultimate costs should be low, since no lasers, fumes, high temperatures, costly materials, or exotic chemicals are involved. Your typical speeds approach 1000 inches per minute.

One big problem with the system: Some prototypes can end up looking like something that missed hitting the reject bin in the Special Education crafts class. Finer filaments can cure this, but build more slowly.

I'm wondering if a better prototyping solution might not involve two steps. Homes are usually built in a "rough" and the "finish" stage. And machinists often work with *near net* stock to try and minimize their total production time. And modelers will often build their model first and then *superdetail* it later.

Possibly some system that gets the shape pretty near the way you want it quickly and crudely, and then the second step which measures and then modifies what you have to give you your final precision fit and finish.

Let's have your thoughts on this.

VHF and Microwave Resources

There are all sorts of interesting things going on in those VHF and microwave frequencies found above several hundred Megahertz. Amateur television ATV, weather fax reception, cable services, satellite downlinks, cellular phones, sports radar, remote controls, radio astronomy, emergency fire service, garage doors, altimeters, test instruments, microwave ovens, and video links are a few examples of hackable opportunities in the VHF and microwave frequency areas.

Unfortunately, all of the hacking rules change in the VHF and microwave range. First, you no longer have individual resistors, capacitors, and inductors.

Instead, the individual resistance, capacitance, and inductance of each component has to be uniquely taken into account, and often done so in a distributed manner. Circuit strays can quickly become totally intolerable. Tolerances of a few thousandths of an inch can make or break any circuit's performance.

Second, testing and measurement often has to be indirect, because many attempts to directly measure a micro-

wave circuit could severely disrupt what you are trying to measure. Not to mention that high frequencies and weak signal levels are involved. Most suitable test equipment also tends to be very specialized, arcane, and quite expensive. And hard to justify.

Third, VHF and microwave parts can be ridiculously costly, since most of them are aimed at gold-plated low volume military uses.

Fourth, the math, the field theory, and all of the advanced technical skills needed to do anything useful at these frequencies goes way beyond electronic fundamentals. A lot of useful microwave information tends to require advanced degree skills, can get very hard to find, and often will even be classified.

And finally, much of microwave design work ends up far more art than science. To this day, black magic can be involved, and you either have the right feel for what you are doing, or your circuits simply will not work.

For this month's resource sidebar, I

have tried to gather together some VHF and microwave stuff you might find of hacker interest.

Obviously, you'll want to start with the old *Radio Amateur's Handbook* published by the ARRL. Many of the ham magazines and club activities will also involve the VHF and microwave frequencies. Per a recent rule change, certain new ham licenses no longer require any Morse code.

Which was long overdue

By far the leading surplus house carrying microwave radar goodies is *Radio Research Instruments*. Only these folks tend to concentrate upon whole systems and refuse to show prices in their flyers. Alternate places to check do include *Fair Radio Sales*, *Surplus Traders*, and in the *Nuts and Volts* shopper.

While utterly ancient, McGraw Hill's *MIT Rad-Lab* series should still be scrounging around on the dusty back shelves of the larger technical libraries. Volume One in particular, Ridenour's *Radar System Engineer-*

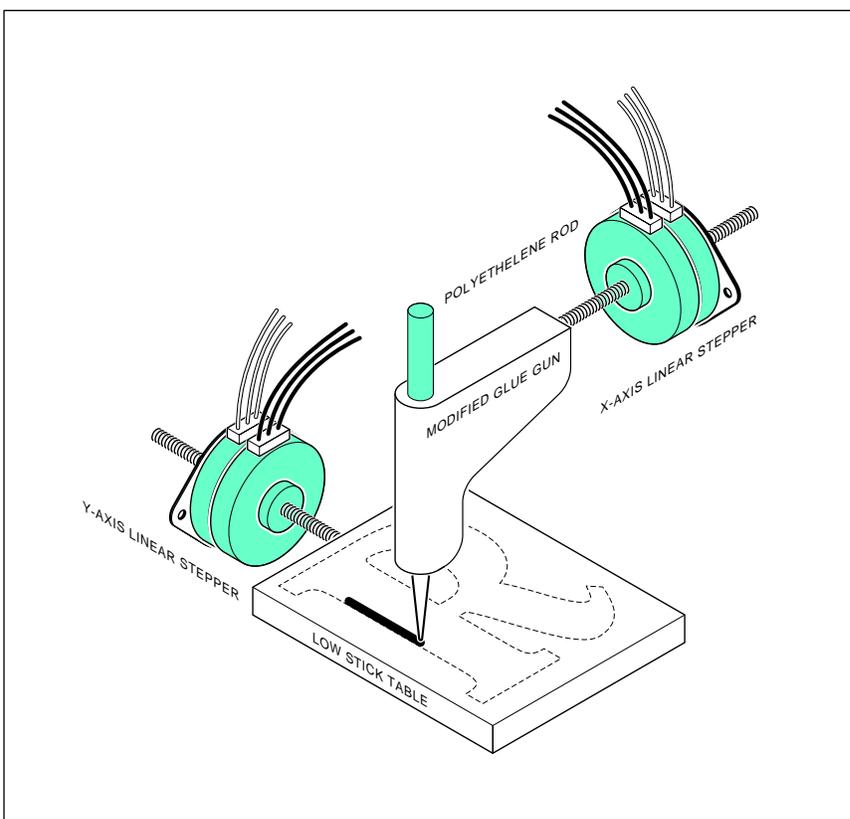


Fig. 5 – A "SANTA CLAUS" MACHINE for producing large display letters. The polyethelene bead from the glue gun is programmed to build up the entire letter one strand at a time. While slow, there are no mold charges and the size and style can be instantly changed. Logos and custom characters are a snap.

VHF & MICROWAVE RESOURCES

ARRL Handbook

225 Main Street
Newington, CT 06111
(203) 666-1541

Defense Electronics

6300 S. Syracuse Way #650
Englewood, CO 80111
(303) 220-0600

Fair Radio Sales

PO Box 1105
Lima, OH 45802
(419) 227-6573

Hewlett-Packard

PO Box 10301
Palo Alto, CA 94303
(415) 857-1501

M/ACom Semiconductor

43 South Avenue
Burlington, MA 01803
(617) 272-3000

Microwave Journal

685 Canton Street
Norwood, MA 02062
(617) 769-9750

Microwave Product Digest

34 Evergreen Place
Tenafly, NJ 07670
(201) 568-5835

Microwaves & RF

611 Route #46 West
Hasbrouck Heights, NJ 07604
(201) 393-6286

Mini-Circuits Labs

PO Box 350166
Brooklyn, NY 11235
(718) 934-4500

Motorola

5005 E McDowell Road
Phoenix, AZ 85008
(800) 521-6274

Nuts & Volts

Box 1111
Placentia, CA 92670
(714) 632-7721

Plessey Semiconductor

13900 Alton Pkwy, Ste 123
Irvine, CA 92718
(714) 455-2950

Radio Research Instruments

584 North Main Street
Waterbury, CT 06704
(203) 792-6666

Rogers

100 S Roosevelt Avenue
Chandler, AZ 85226
(602) 961-1382

SGS-Thomson Microelectronics

211 Commerce Drive
Montgomeryville, PA 18936
(215) 362-8500

Surplus Trader

Winters Lane Box 276
Alburg, VT 05440
(514) 739-9328

ing has been reprinted a number of times and remains highly useful to this day. A pair of more recent classics are Skolnik's *Introduction to Radar Systems* and his *Radar Handbook*.

As with any field, the free trade journals are your foremost day-to-day info source. While there are several dozen, four I've found useful include *Microwaves and RF*, the *Microwave Journal*, *Microwave Product Digest*, and *Defense Electronics*.

Be sure to check out *Mini-Circuits Labs* for all their low cost broadband amplifier chips, and *Plessey* for their unusual new *Satellite Cable and TV Integrated Circuit Handbook*. They also have lots of info on frequency synthesis and high speed dividers.

Hewlett Packard, of course, makes all kinds of microwave components, as well as high performance micro-

wave and VHF test instruments. And *Motorola* has a wide variety of high frequency semiconductor chips and application notes available.

Two other chip sources include *SGS* and *M/A Com*, while *Rogers* supplies printed circuit materials and oddball dielectrics useful for microwaves.

Well, that should be enough to get you started. Please let me know what else you think should be added to our resource files.

New Tech Literature

From *Sony*, a *Memory Data Book*. They also have lots of great stuff on A/D and D/A converters. From *Rohm*, an *Electronic Components Catalog* which includes details on their FM stereo broadcasters and lots of other eminently hackable goodies.

From *LSI Logic*, a new group of

LR64700 video compression chips that should revolutionize both still and moving picture image storage and transmission.

I do get lots of calls asking about hacker friendly sources for custom crystals. Two of my favorite sources are *Statek* for low frequencies and *Crystek* for higher frequencies. Both have catalogs, data sheets, and ap notes available.

A newly detailed bibliography on magnetic refrigeration is available through Jerry Hagen at his own *Cory Laboratories*. Our unusual hacker magazine for the month is *Homebuilt Rotorcraft* from the *Rotary Flight International* folks, while that free *Maxim Engineering Journal* has all sorts of semiconductor goodies in it. Especially for audio/video switches and power supplies that work off a single AA cell.

Free samples of *Powerpole* connectors are available from *Anderson Power Products Inc*. These are both snap-together modular and sexless. They should be ideal for such things as solar panels, but perhaps not quite rugged enough for use in cave rescue communications.

An interesting sandblasting catalog is available from *National Sandblast*. This is one quick way to spruce up any metal on your prototypes.

Turning to my own products, for the fundamentals of digital integrated circuits, do check into my *TTL Cookbook* and *CMOS Cookbook*. Or to pick up all the "oldies but goodies" at once, try out my *Lancaster Classics Library*.

We also now have the *Hardware Hacker III* reprints available, which has the latest and best of all these columns in them. All edited, revised, corrected, and indexed.

Finally, I do have a new and free mailer for you which includes dozens of insider hardware hacking secret resources.

Write or call for info.

Our usual reminder here that most of the items mentioned appear either in the *Names and Numbers* appendix or the *Microwave Resources* sidebar.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8-5 in *Mountain Standard Time*. Let's hear from you. ♦

Don Lancaster's

Hardware Hacker

June, 1991

Electronic tuning diodes
Two unusual newsletters
Parametric Amplification
Association book resources
Preventing modem dropouts

We might start off with the reminder that we do have our RE technical helpline available for your use per the box below. Here is where you can go for tech help, referral to highly qualified consultants, for book and software purchases, and for general off-the-wall networking.

Because of time and funding limits, this service is strictly restricted to US *Hardware Hacker* readers only. Your best calling times are on weekdays 8-5 *Mountain Standard time*. Before you call, please re-read the *entire* column and especially the *Names and Numbers* and *Resource* boxes. Hardware Hackers calling without a pencil or a pen handy will get chopped up and fed to the cows.

You could also reach me by way of my personal BBS, otherwise known as *GENie PSRT*. Call (800) 638-9636 for voice connect info.

But, please do note that I am an independent developer and author sitting here on my sand dune in the middle of the Upper Sonoran desert. I have very little input to any **Radio-Electronics** editorial policy and know next to nothing about RE projects by other authors. For more info on these, call Brian Fenton at RE editorial (516) 293-3000, or else you might use the **Radio Electronics** BBS you'll find at (516) 293-2283.

Yeah, I sometimes do welcome any visitors that call in advance. But do note that Gurus are supposed to be hard to reach, because (A) it adds to the mystique, and (B) the Guru's and Swami's Union Local #415 rules demand it. At any rate, there is a seven hour drive involved in reaching the nearest airport from here. I won't even mention the deadly Gila Monsters or hostile Indians.

Every once in a while I'll get a call that sounds reasonable at the time, but after thinking things over... For instance, one *Hardware Hacker* did want to crystal control that low cost BA1404 FM stereo broadcaster we've looked at in past issues. He wanted to do this so that several actors in a play

could be on the same frequency.

Uh, whoops. Yew caint get there frum here. Sure, you can crystal control your BA1404. And you certainly can put as many of them as you want on the same frequency. But one of the key properties of FM reception is that you will only receive your *strongest* station, with virtually zero pickup of any of those others. This normally desirable action is known as the *FM Capture effect* and is caused by the hard limiting present in virtually all FM receivers. As little as a fraction of a decibel can cause any one signal to utterly and totally dominate.

Sorry about that. We return you to our column already in progress...

Electronic Tuning

The traditional method of tuning a resonant circuit to your desired frequency is to use some adjustable or variable capacitor. While obvious and cheap, these capacitors are often large and sometimes expensive; could be sensitive to fields and vibration; and usually require human intervention for their use. These days, it is much better to go to *electronic tuning* methods.

The simplest method of electronic tuning is to never do it. As much as possible, you purposely design out any need for a variable capacitor or a direct replacement. For instance, you use digitally synthesized frequencies instead of any local oscillator or BFO. You use switched capacitor filters or active filters that are tunable by an

input frequency or voltage. Or you can use ceramic or SAW filters that are so precise and so repeatable that zero adjustment is needed. You also tend to use a few higher quality filters, rather than lots of individually tuned and cascaded LC circuits.

But after all of this, there remain times and places where you'll still need a few electronically variable capacitors. Selecting a station on a radio or TV are obvious examples.

One very popular, well performing, and ultra low cost electronic tuning method is called a *varactor diode* or simply a *varicap*. Varactor diodes are diodes which have been optimized to look and behave as a high quality electrically variable capacitor.

Most any diode conducts current in the forward direction and blocks it in the reverse direction. Specifically, when you reverse bias a diode, you create a *depletion region* containing neither electrons nor holes. As you increase your reverse bias, this depletion region gets thicker, and vice versa. Thus, *any* diode will behave as an electrically variable capacitance as you vary its reverse bias voltage.

For most diodes, this unavoidable depletion region capacitance is a flaw that restricts your maximum speed of operation. But in a varactor diode, the depletion region capacitance is purposely made rather large, quite high quality, and very controllable.

Figure one shows you a typical circuit. From the electrical control

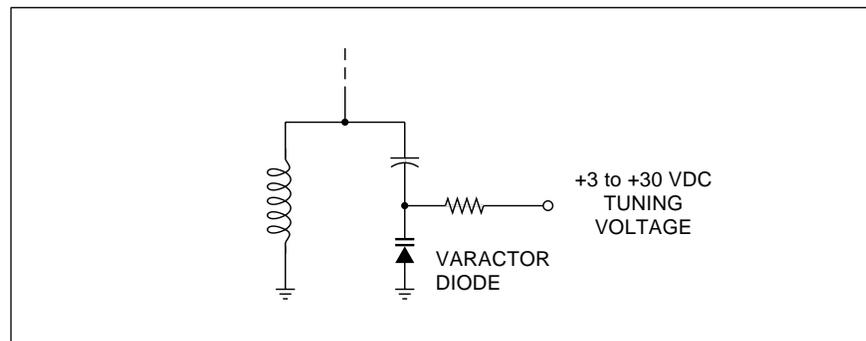


Fig. 1 – ELECTRONIC TUNING USING A VARACTOR DIODE. The diode depletion layer capacitance varies with the applied reverse bias. The large series capacitor serves as a dc block to prevent shorting out the tuning voltage.

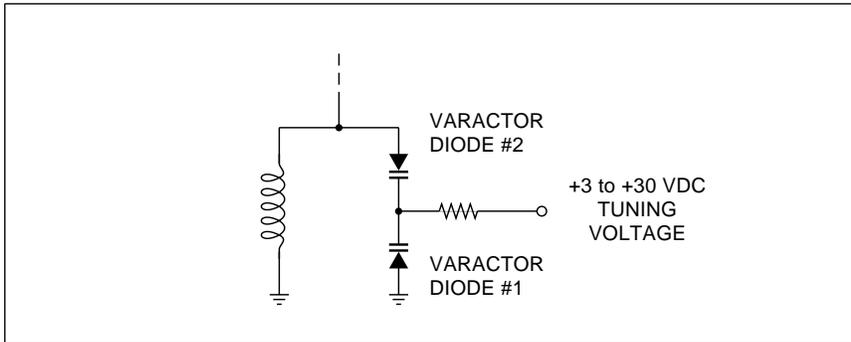


Fig. 2 – A PAIR OF BACK-TO-BACK varactor diodes can be used to prevent larger signals from detuning themselves. A positive signal swing raises the capacity of one varactor and lowers that of the other. The changes largely cancel out.

side, you can simply reverse bias your diode by way of a large series resistance or some other method that has a very high RF impedance. When you change the value of this voltage, you electrically change the capacitance of your varactor's depletion region, and thus tune your circuit. Typically, you change your tuning voltage over a 3 to 30 volt reverse bias range.

On the resonant circuit side, you do have to provide a DC return path to ground for the tuning voltage bias. You also do have to provide a series blocking capacitor to keep any other DC path from shorting out your diode. Normally this series capacitor is very much larger than the varactor's capacity, so it does not significantly alter your resonance calculations.

Sadly, the varactor's capacitance changes nonlinearly with the reverse voltage. Depending on the varactor, you might have 60 picofarads at 1 volt reverse bias, 45 pf at 2 volts, and 18 pf at 20 volts. Thus, your first couple of

volts of reverse bias will by far give you the most variation. The plot of capacitance versus reverse voltage is roughly linear when it gets plotted on semilog paper.

Varicap capacities can go from a fraction of a picofarad with exotic microwave devices on up to several hundred or more picofarads for use in audio filters or AM tuning. You can sometimes use giant silicon power diodes for lower frequency varactor experiments. But the Q will often be low when you try this, and the tuning range will be limited.

The *capacitance range* of a varicap is usually defined as the ratio between your 3 and 30 volt bias settings. An ordinary varactor will often have a capacitance range of 3:1.

But note that a frequency change varies with the *square root* of your capacitance change in any resonant circuit. So, this type of 3:1 varactor can only shift a resonant frequency by 1.73 or so. Not all that much.

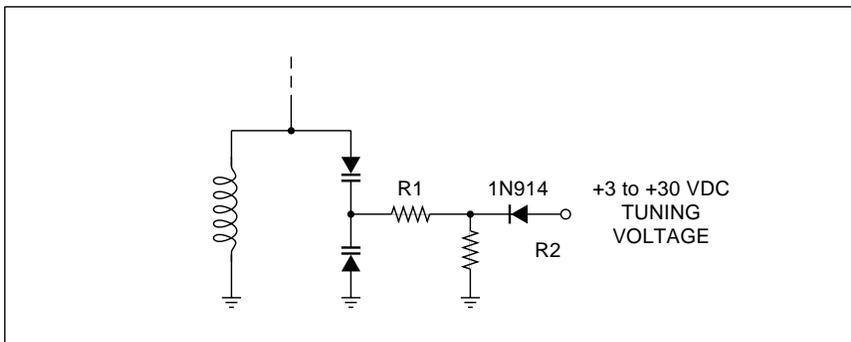


Fig. 3 – A TEMPERATURE COMPENSATED varactor tuner. The forward drop temperature drift of the ordinary diode can be used to offset the capacitance drift of the reverse biased tuning varactors. Resistor R1 has to be large enough to not load the tank circuit. Resistor R2 adjusts the tempco.

One way to increase the range of a varicap is to cheat and use a lower bias voltage. Your capacitance will usually increase dramatically for very low values of reverse bias. But at this point the diode will start to conduct and very much reduce the available Q or selectivity for your tuned circuit. The linearity will also be awful.

For wider tuning ranges, special varicaps are obtainable which have different doping profiles. Varicaps with a medium tuning range have an *abrupt* doping profile, while those with very high tuning ranges use a *hyperabrupt* profile.

The tradeoffs for a wider tuning range are more nonlinearity, somewhat higher cost, lower circuit Q, and harder tuning. You'll also become vastly more sensitive to noise and the precision of your tuning voltage.

The AM broadcast frequencies of 550 to 1650 kilohertz have a 3:1 range. Thus, you should use a hyperabrupt varactor having at least a 9:1 and preferably a 10:1 tuning range here. The hyperabrupt *Motorola* MVAM108 is one good choice here, having an extreme 15:1 range.

Those television frequencies are spread out over a very wide range. To prevent having to tune these all at once, three varactor tuners are separately used in several individually selected circuits. One for the lower VHF channels 2-6; a second for the high VHF channels 7-13; and a third for the remaining UHF channels. And sometimes a fourth for special cable channels. Note that there is a big frequency gap between channel 6 and channel 7 that holds the FM broadcast band and emergency services.

Should you instead want to restrict the tuning range of a varicap, you can either put a fixed capacitor in parallel with it or else use a narrower voltage control range. The fixed parallel cap is often the better choice.

Varactors work best with tuned signals in the microvolt range. Should your signals being tuned get above several millivolts, the signals themselves can add to or subtract from the tuning voltage. Thus, your positive signal excursions will increase the resonant frequency and vice versa. Which can introduce moderate to severe second harmonic distortion.

You might resolve this possible

distortion problem by using a pair of varactor diodes as shown in figure two. The two varactors are in parallel as far as the DC tuning voltage goes, but are in series with any signals being tuned. Thus, on a positive peak, the capacitance of the first varicap will increase as the other decreases, and largely cancel each other out.

Dual varactors in a single package are becoming popular. The *Motorola MV104* is one example. Note that two capacitors in series give you *one half* the total capacitance. Be sure to allow for this in your designs.

It is extremely important to have a *very* stable reference for your tuning voltage, since any drift at all could detune your circuit. If possible, you will also want to use some sort of feedback to keep your tuning locked on channel. Various types of AFC (automatic frequency control) can sometimes do this for you.

Sadly, varactors drift over temperature. Their values will increase with an increasing temperature. One typical value is in the 200 parts per million range. On the other hand, a regular diode that is *forward* biased should have a current-dependent drift with a negative tempco.

Figure three shows how to add an ordinary diode in series with your tuning voltage to temperature compensate a varactor diode. The load resistor of the diode is adjusted to give a minimum overall drift. Sometimes a parallel capacitor can also be added having a chosen tempco.

A precise temperature compensation over a wide range could get tricky. At the least, everything has to be tightly heatsunk together. More details appear in the *Motorola Ap Note #AN551*.

As we've just seen, *Motorola* is one leading supplier of a wide variety of low cost and easy-to-get varactor diodes. Some cost under a dollar. See their *RF Device Data II* handbook for data sheets and ap notes.

Parametric Amplifiers

Surprisingly, varactor diodes were not initially designed for electronic tuning. Instead, they were created for a unique beastie once known as a *parametric amplifier*. Back in the days of tube style UHF tv tuners with 35 decibel noise figures, the idea of an

ultra low noise, high gain, and high frequency amplifier that used nothing but a diode sounded like a great idea.

Today, low noise and high gain microwave transistors are a buck each from such outfits as *Mini-Circuits Lab* and *Avantek*. Paramps are largely limited to esoteric ultra-microwave lab circuits and for optical and infrared experiments. Although I do strongly suspect you'll shortly see a stunning resurgence of paramps in a brand new application area.

Figure four shows you how the parametric amplifier works. This is exactly the same idea as pumping a swing on the playground. The local oscillator called the *pump frequency* causes the capacitance of a varactor to change in a time varying manner. The "parameter" here we are varying is the diode capacitance. A low level input signal known as the *input frequency* is also routed to the same time varying capacitor. A filter extracts an output signal known as the *idler frequency*.

The net result can be a very strong and low noise amplification and a possible frequency conversion for your input signals. Since a purely reactive capacitor is in use, there are theoretically none of those noise problems associated with resistance or the traditional tube or semiconductor amplifier circuits. I once used a plain

old three cent 1N914 computer diode to produce 20 decibels of gain and a 2 decibel noise figure at 600 MHz. The diode was dc back biased to -3 volts or so and a suitable pump frequency was capacitively superimposed. Long ago and far away.

Paramps can be designed as upconverters with gain, as downconverters with loss, or as negative resistance devices with potentially high gain but possible instabilities.

The key math behind paramps is known as the *Manley-Rowe* relations. One horse's mouth classic on this subject is Blackwell and Kotzebue's *Semiconductor Diode Parametric Amplifiers*, published by Prentice Hall, way back in 1961. Included is a good summary of Manley-Rowe plus an extensive bibliography. For more modern info on paramps, check out the *Dialog Information Service*.

Professional Society Libraries

As we've seen a number of times in the past, that *Uhlricht's Periodicals Dictionary* on the reference shelf at your local library is overwhelmingly your single most important hardware hacking resource, bar none.

But there's another set of books on the same shelf titled the *Encyclopedia of Associations*, which you might also find quite useful.

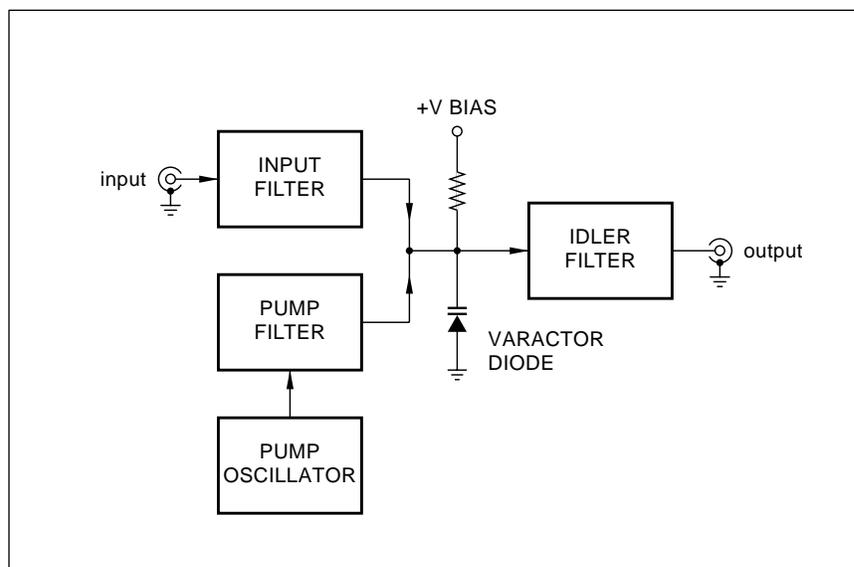


Fig. 4 – A VARACTOR DIODE PARAMETRIC AMPLIFIER in which a diode provides low noise amplification. The pump frequency causes the varactor capacitance to vary in such a time-dependent "parametric" way that its interaction with the input frequency produces an amplified output at the idler frequency.

Hardware Hacker

There are zillions of professional societies, most of which do seem outrageously expensive and who simply do not deliver what they think they do. On the other hand, many of these groups have association bookstores that do have outstanding tutorials, reprints, and information real hard to find elsewhere.

To get you started, our resource sidebar for this month lists a few of the professional organizations. Here is a brief rundown...

The *American Association for the Advancement of Science* publishes the "must have" *Science* magazine and provides outstanding book reviews. The *Association of Energy Engineers* carries dozens of books including a *Small Power Production Manual* and *Efficient Electrical Systems Design*.

The old *Institute of Electrical and Electronic Engineers* is a rather poor performer that is way overblown and far overrated to the point of being a ripoff. But their reference books do include *Visual Communication Systems* and *Navigation: Land, Sea, Air, and Space*.

The *American Society of Materials* has hundreds of books on just about anything mechanical. Their *Metals Handbook* series are classics.

The *Society of Motion Picture and Television Engineers* is big on time codes, on video production, and other hard-to-find resources. The *Journal of the Audio Engineering Society* is your foremost resource for any music synthesizer theory, and all other audio.

And we've already seen that the *Society of Automotive Engineers* has lots of great automotive electronics books. And finally, one real sleeper, that *Society of Photo-Optical Instrumentation Engineers* which publish a Milestone Series which includes such topics as *Fiber Optic Gyroscopes*, *Digital Image Processing*, and *Ultra-high Speed Photography*.

Naturally, there are bunches more where these come from. For the first of our two contests this month, simply tell me about any professional organization in any field that has book or publication resources of possible interest to hardware hackers. There will be all the usual *Incredible Secret Money Machine* book prizes, with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for the very best.

Teleprotection Surprises

One of the ruder surprises you'll discover when you first start using a modem extensively is that anyone who

picks up any extension phone could blast you off the air. This can get especially frustrating and infuriating just before the end of a long and costly upload or download.

Radio Shack offers a product called their 43-107 *Teleprotector*. It costs eight bucks and its only tiny problem is that it may end up working *too good* for you.

Any inactive telephone line has around 48 volts of direct current on it. When the first phone is picked up, the working voltage drops down into the 6-8 volt range. So, if you simply put a plain old voltmeter across the red and green wires on your extension phone, you can quickly tell if the phone line is in use by another extension.

Figure five shows you the circuit for their teleprotector, along with some possible mods. An extension phone normally uses only the red and green wires. The teleprotector breaks the green wire and inserts a full wave diode bridge. The purpose of this full wave bridge is to make the current in the use-sensing circuit always go in the same direction, even during the ringing or if the phone polarity somehow ends up backwards.

Initially, there is only a very high value 390K resistor inside the bridge. This is much too large a series value to let the phone work. When you pick up the phone, your full available line voltage initially appears across this resistor. Should you have at least 18.7 volts available (meaning that there is no other extension in use), your SCR (Silicon Controlled Rectifier) turns on, stays on, and will let the extension operate. If another phone is being used, there will not be enough voltage to turn on the gate of the SCR, and the extension will remain off.

So far so good. Any SCR will stay on only so long as its main anode to cathode current drops to zero. This particular SCR can get turned off one of two ways. If you hang up your protected extension, the current in the green wire obviously drops to zero and resets you for the next call.

But there's also that mysterious 8.7 volt zener *in series* with your SCR. Now, should some other phone get picked up, there won't be enough voltage left on the line to keep the zener conducting, so the SCR turns off, as does the extension phone.

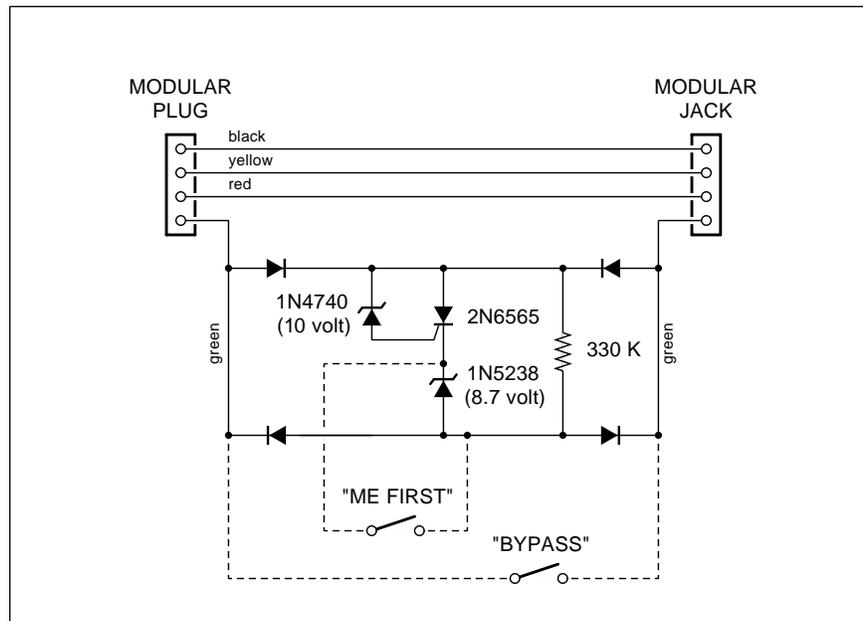


Fig. 5 – CIRCUIT DIAGRAM for the Radio Shack 43-107 teleprotector, along with two possible mods. Unmodified, the extension phone is only allowed on the line when no other phone or modem is in use. The BYPASS switch will defeat the teleprotector entirely; the ME FIRST switch lets your extension remain active if another phone gets picked up during a call.

Thus, your protected extension phone will never turn on if another phone is off hook. Should you be using your protected extension phone and should another one get picked up, you will get unceremoniously cut off the line!

All of which tells us that their teleprotector works *exactly* as they advertise. There is no way to eavesdrop with a teleprotected extension phone. There is also no way to let the teleprotected extension blast your modem off the air. Or a FAX machine for that matter.

Another trick is to hook up their teleprotector up to your answering machine. When you pick up your remote extension, your answering machine drops off the line, stopping the now unwanted message. Which also can be handy.

One key point: Your teleprotector does *not* go on the modem phone. It goes on the interfering extension.

Now for the big problems. Your teleprotected extension can *not* be used for any conferencing! You also cannot have a receptionist answer by picking up with their teleprotected extension and then listening in long enough to verify the correct person picked up the call.

Two possible circuit mods are also shown in figure five that might be more suited to you should you need conferencing, but your main goal is to eliminate any modem blasting. A BYPASS switch completely defeats the teleprotecting. Whenever any two phone conversations are desired, you slide this switch into its BYPASS position, shorting the works out. You do, of course, have to remember to flip the switch back after any needed two phone conversations.

Closing the ME FIRST switch lets the protected phone initiate or receive a call so long as it is the first phone picked up. It will stay active should additional phones be picked up, so two-phone conferencing can still be done. But the protected phone still can no longer break in on a modem or fax in progress.

If you really want to get hairy, you could even let your protected phone purposely break in on any ongoing voice conversation when in the ME FIRST position. Just shout at the other person to pick up their phone. Once

ASSOCIATION BOOKSTORE RESOURCES

American Association for the Advancement of Science

1333 H Street NW
Washington, DC 20005
(202) 326-6400

American Society of Materials

PO Box 473
Novelty, OH 44072
(800) 368-9800

Association of Energy Engineers

PO Box 1026
Lilburn, GA 30226
(404) 925-9558

Audio Engineering Society

60 East 42nd Street, Rm. 2520
New York City, NY 10165
(212) 661-8528

Institute of Electrical and Electronic Engineers

445 Hoes Lane
Piscataway, NJ 08855
(201) 981-0060

Society of Automotive Engineers

400 Commonwealth Drive
Warrendale, PA 15096
(412) 776-4841

Society of Motion Picture and Television Engineers

595 West Harsdale Avenue
White Plains, NY 10607
(914) 761-1100

Society of Photo-Optical Instrumentation Engineers

PO Box 10
Bellingham, WA 98227
(206) 676-3290

you are sure their phone is picked up, hang your phone up for half a second, and pick it up again. Both of you should now be in conference.

But my particular setup requires *three* phones, any-way conferencing, and no modem blasting. As a second contest for this month, let's have your thoughts on how to elegantly handle this problem.

The *Radio Shack* teleprotector unit is cheap enough that you probably would not want to build one up from scratch. But should you decide to experiment completely on your own, that oddball 2N6565 sensitive gate SCR is a *Teccor* product available by way of *Mouser Electronics*.

New Tech Literature

From *Signetics/Phillips*, an outstanding new *RF Communications* data handbook. Included are full use details of their hot new NE602 active VHF mixers, info on cellular phone chips, and frequency synthesizers.

Also from *Signetics/Phillips*, a new *Telecom IC* shortform catalog. And from *Brooktree*, a *Product Databook* on all their A/D, D/A, color palette, and video chips.

Our featured free software deal for this month is the *High Performance Electronics Selection Guide* offered by *Burr-Brown*.

One marketing firm aggressively seeking *tested* and *developed* low end

consumer electronics items for use on an ongoing royalty basis is Mark Gotteib's *DesignTech*.

Two rather impressive "labor of love" high quality newsletters are Don Parham's *Homebuilt Rotorcraft* for the Gyro Gearloose crowd; plus Ed Zimmer's *Inventor-Entrepreneur Network Newsletter*, that's intended mostly for Michigan hackers.

A pair of interesting trade journals include *Medical Electronic Products* and *Medical Equipment Designer*. Yes, they have info on brain wave electrodes. But do make certain you know what you are doing before you hotwire your neighbor's car.

Turning to my own products, for the fundamentals of microprocessors and microcomputers check into my *Micro Cookbook I* and *Micro Cookbook II*.

Or, to pick up all those "oldies but goodies" at once, do check into my *Lancaster Classics Library*.

We also now have the *Hardware Hacker III* reprints available, which have the latest and best of all these columns in them. All edited, revised, corrected, and indexed.

Finally, I do have a new and free mailer for you which includes dozens of insider hardware hacking secret resources. Write or call for info.

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Don Lancaster's

Hardware Hacker

July, 1991

Power electronic resources
Video crosshatch generator
More wavelet breakthroughs
Secrets of video compression
Understanding transformation

I do seem to get several helpline calls each day from those of you who just "can't find" a technical paper at your local library. It's getting so bad that I am thinking of starting up a special "Couldn't find a pig in a dishpan" contest.

Pretty near all libraries provide the *Interlibrary Loan Services*, through which you can get any copy of any paper from anywhere. All you have to do is ask. There's also the *UMI* folks that can very quickly ship you a copy of anything from anywhere. Finally, at extra cost, you can instantly get a copy of any paper by way of the *Dialog Information Service* that is becoming available at most libraries.

More on Wavelets

For those of you that came in late, there's a math revolution taking place that we are intently following as an ongoing subject here in *Hardware Hacker*. This involves *wavelet theory*, a profound and an earth-shattering improvement on klunky old *Fourier* transformation which is *certain* to totally change just about any and all advanced electronic topics.

There's now a brand new book on wavelets that aims at becoming the "horses mouth" classic. It is known as *Wavelets* (a catchy title, eh what?). And authored by a long list of name brand wavelet biggies which start with G. Beylkin. It is published by *Jones and Bartlett*. It is not easy reading.

Meanwhile, a spunky new outfit by the name of *Aware Incorporated* is -er- making a large splash in actual out-the-door wavelet products. They have some wavelet demo and nice simulation software that you can run on a PC, and they seem to be the first ones out the gate with new *wavelet transform accelerator* chips. Their initial chips are intended for video compression of 512 x 512 images to either eight or eleven bit accuracy.

There seems to be several dozen new wavelet papers being released per month now, so it really is a zoo out there. This new wavelet tool is so fundamental and so important that

everybody from the oil exploration geologists to cardiologists appear to be showing intense interest.

Most of these wavelet papers are, of course, totally unreadable. But to tune yourself into them, you use the *Dialog Information Service* from your local library, and zeroing in on their *Inspec*, *Compendex*, or *Mathsci* data bases. A monthly update of all the latest key abstracts should cost you under \$20. While you can get the actual papers through *Dialog*, they are much cheaper through *UMI*, and cheaper still through the *Interlibrary Loan* service.

Wavelets operate by *transforming* arrays of numbers into other arrays of numbers. Unlike the classic *Fourier* transformations, you can simply and quickly zero in on specific portions of a transformation problem, and can do so both locally and globally. You also can eliminate "windowing" problems.

Understanding Transforms

Before we take a new look at *video compression*, which is one of hottest emerging new wavelet uses, let's ask the even more fundamental question: Just what is a transform? Why are they so crucially important? And why are

certain new hardware hacking doors permanently closed to you if you do not learn to use and love transforms?

Well, a *transform* is simply finding a different way of looking at some problem. Done properly, a transform should let something "magic" happen. What kind of magic? That depends. Transforms may just change things so they appear differently; may break something down into its fundamental parts; may extract non-obvious stuff in non-obvious ways; could help you separate signals from noise; may let you do more with less; or can perform any of a number of other unique (and often unexpected) tasks.

For instance, you can either listen to music or else *transform* that music to notes-and-staff notation on a piece of paper. Beside it being a compact way of representing a song, the sheet music notation lets you know what is going to happen next. It also, for better or worse, standardizes the way the song is supposed to be played.

These days, most transforms are done digitally. As figure one shows us, to do a transform, you take a pile of numbers in a grouping called an *array* and then apply some rule or set of

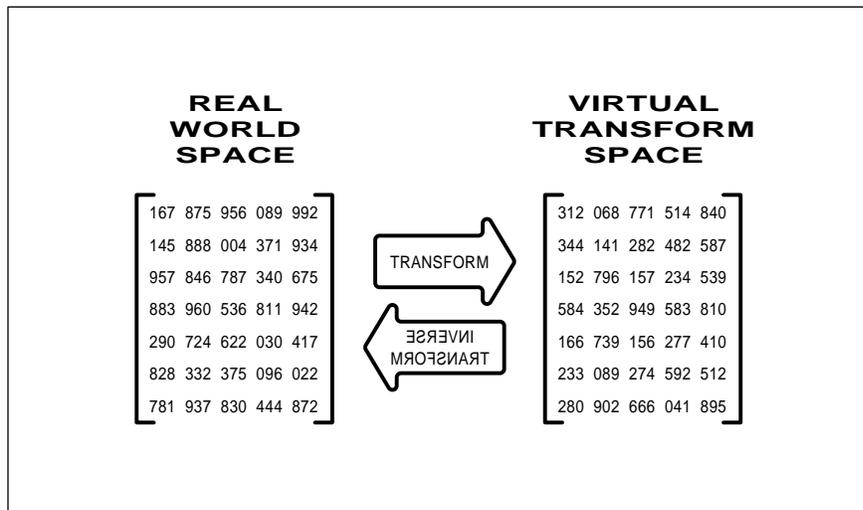


Fig. 1 – A DIGITAL TRANSFORM takes an array of numbers that usually represents something from the real world. It then applies a math rule or rules to those numbers to create a new but related array of numbers in an imaginary transform space. Certain "magic" things will happen in the transformation process that gives you elegant new ways to solve electronic problems.

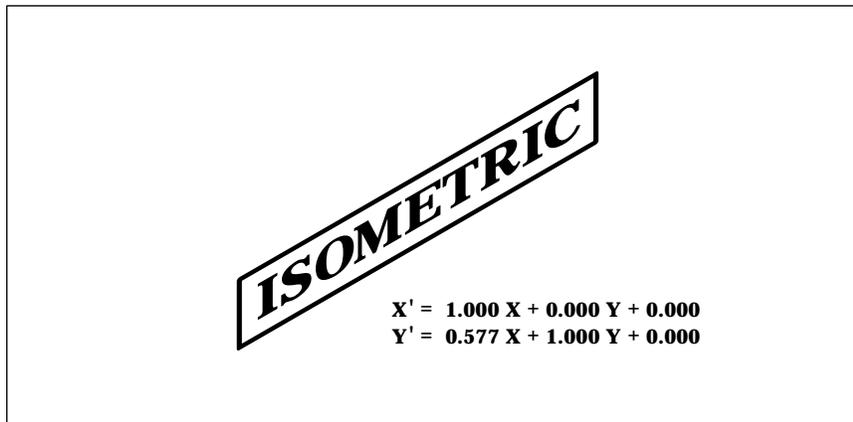


Fig. 2 – THE LINEAR GRAPHICS TRANSFORM is both a simple and very important example of transform use. Here ordinary graphics and lettering have gotten changed into isometric lettering by using the math shown.

rules to all these numbers. These rules will most often involve multiplying, adding, trig functions, shifting, and other math stuff. Your result is a second array that holds transformed "answers".

You might call your first array the *real world plane* and the second array the *transform plane*. Think of them as two different worlds. If you can undo what you just attempted with your transform, the transform is said to be *lossless*, and your reverse process is called an *inverse transform*.

For instance, you might take a picture and transform it. You might

then modify the new numbers in the transform plane to extract the edge information, to recognize patterns, count objects, look for differences, or deblur the image. A final inverse transformation could then give you a "new" picture which has changed in some way from the original.

One fairly simple yet extremely important transform is known as the *linear graphical transform*. This is used to change your sizing, position, rotation, and shape of an image.

The *PostScript* computer language is especially adept at making both linear and nonlinear transforms. And,

unlike many other languages, *PostScript* automatically can do so continuously, invisibly, and on the fly, maintaining a separate *user space* and a machine-dependent *device space*.

Figure two shows you a simple linear graphical transform that can convert plain lettering into isometric lettering. Let's look at some numbers. The linear graphical transform takes any point x,y in your original artwork and converts it into a new point x',y' by using these formulas...

$$\begin{aligned} x' &= Ax + Cy + E \\ y' &= Bx + Dy + F \end{aligned}$$

Values A through F are plain old constant numbers for any selected transformation. If we think of these as some array of [A B C D E F], your A value determines the *horizontal scale*. The B value decides how much *climb* you are going to get. And C decides how much *lean*. The D value sets the *vertical scale*. The E value provides for a *horizontal shift*, while the final F value sets the *vertical shift*.

For instance, you might use A and D to separately change the width and height of a font character or message. A positive C value would make your message oblique or italic, while a negative C would do reverse italics. Similarly, a positive or negative E can give you a superscript or subscript.

And a sneaky trick involving sines and cosines lets you *rotate* an image, again just by altering A through F in just the right way. Specifically, if θ is your angle of rotation, just use...

$$\begin{aligned} A &= \cos\theta & D &= \cos\theta \\ B &= \sin\theta & E &= 0 \\ C &= -\sin\theta & F &= 0 \end{aligned}$$

Which may look ugly but works like a champ. And in general, the linear graphics transform lets you translate, scale, or rotate most any 2-D object.

The point here is that most other transforms work exactly the same way. You can start off with some pile of numbers, apply some rules to them, and end up with a second pile of numbers. And some very good things can happen along the way.

The granddaddy transform of them all is known as the *Fourier* transform, while its computer implementation is called a *Fast Fourier Transform* or one of its improved offspring, *Fourier*

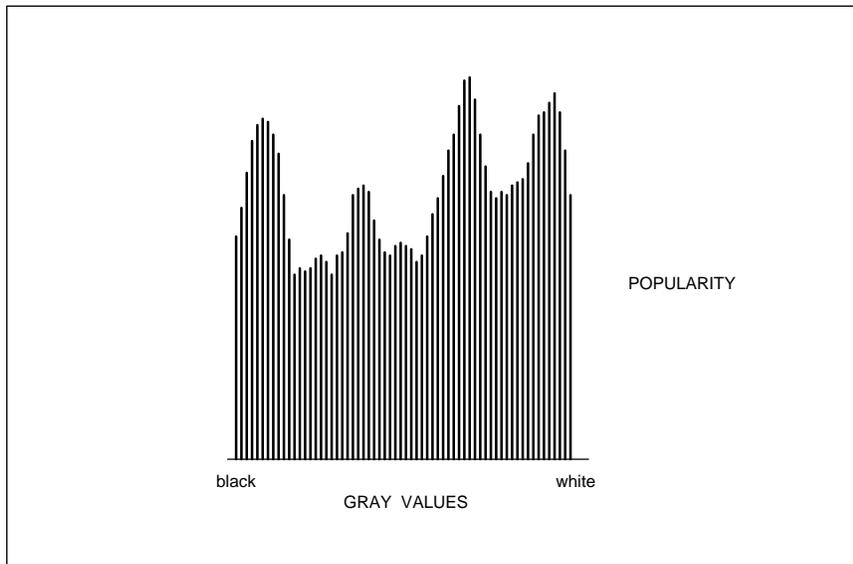


Fig. 3 – A HISTOGRAM OF A TYPICAL VIDEO PICTURE can show you the "popularity" of each gray level. Since no use gets made of the untransformed edge, pattern, texture, and area info, only a very small amount of useful data compression is actually possible.

transforms move you from the real world *frequency domain* on over into the *time domain*.

As an example, if you use Fourier transforms to analyze a square wave, you will break the wave down into a fundamental sinewave and weaker third, fifth, seventh, and other odd higher harmonics. Similarly, you can take a pile of sinewaves and add them together by using the inverse Fourier transform in order to get the actual squarewave back.

Finding the frequencies is called *analysis*; Building the waveform is known as *synthesis*.

Fourier transformation and all its newer offspring get used for nearly *all* the advanced electronic applications. These include detecting earthquakes and heart attacks, robotic vision, side looking radar, in video compression, picture deblurring, for high definition television, music synthesizers, sonar, geophysical exploration, holograms, and spectrum analysis.

As we've seen, the real excitement behind wavelets is that it does all of the things that Fourier transformation already does. Only wavelets do it far faster, far better, and much cheaper. Wavelet transformations also seem adept at localizing certain features, such as the leading and trailing edges of a square wave. Which is something that gives Fourier fits.

Probably the hottest example of wavelet mania today involves...

Video Compression

We are smack in the midst of a multimedia revolution that will let you directly manipulate all studio quality pictures, artwork, and even superb animation on any personal computer. The big problem here is to squash the information content of a high quality color image down into a manageable space without degrading the picture too much. The HDTV *high definition television* people are grappling with their version of the same problem – How can you get all of those pixels squashed down into an acceptable transmission bandwidth?

Wavelets promise an exciting new solution to video compression. One that is fast, cheap, easily implemented in hardware, massively parallel, low on artifacts, and can give you compressions as high as 100:1.

And what is even more exciting, it seems that researchers in human and animal vision are freshly discovering that either the wavelets or something very much akin to them is involved in nature's way of resolving the same types of visual and aural problems. So, something really heavy seems to be coming down here.

What makes a picture different from completely random pixels? The usual answers are *edges, patterns, and large areas* where the colors and shading change little if at all. If a picture is nearly random and if you must have everything in that picture, then there isn't much you can do to squash it down to a smaller size. On the other hand, if there are plenty of edges, patterns, and large areas, and if some amount of visual degradation can be allowed, then you can often squash your picture down considerably, possibly as much as 100:1.

Figure three shows you a *histogram* of a typical image. In this case, there are 256 gray levels, and each level gets used by the height of its bar as shown. Despite your usual image having lots of edges, patterns, and big areas, the histogram looks more or less like random noise.

But, apply a wavelet transform to your same picture, and you get the surprising histogram of figure four. Wavelets are chosen that zero in on

extracting key edge, pattern, and area information. *The amazing result is that most of the numbers in your new histogram are zero and thus can be safely ignored!*

An array with lots of zeros in it is called a *sparse data set*. By going to a fancy *Huffman* or any similar coding scheme, sparse data sets can be stored or transmitted much more compactly than an array in which every value is equally important.

There is usually a two step process involved in video compaction. You first try to concentrate all the picture energy in as few array numbers as is possible, zeroing out as many of the others as you can. Then you code the final results as densely as you can.

As a reminder, a wavelet transform works just like any other transform. You start off with the first pile of numbers, play several simple math games with them, and end up with the second pile of new numbers. In the wavelet case, your math games are simple additions, shifts, and rotations. Math which is far less hairy than the fancy trig needed with conventional Fourier or DCT Transforms.

There are many popular wavelets, and new ones are getting discovered daily. A typical compression wavelet need act only on a very few adjacent values in your original array and can use only simple shifts and adds. The

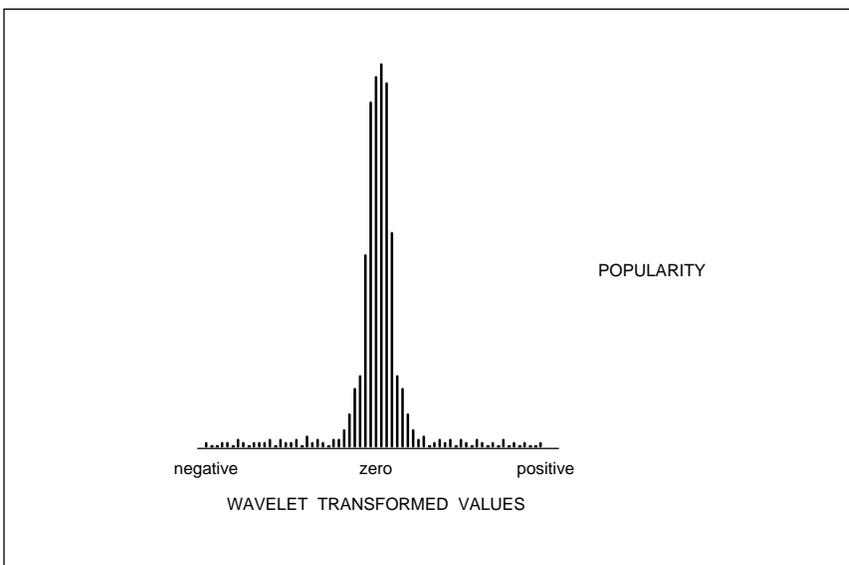


Fig. 4 – WAVELET TRANSFORMED HISTOGRAM OF THE SAME PICTURE creates a "sparse" data set having many zero values, by concentrating and redirecting the picture energy. Yet EVERY detail of the original picture is fully and exactly preserved! Extensive compression can now be done.

wavelets are usually applied to rows in the array, and then reapplied to the resultant columns.

So far, we have thrown nothing whatsoever away. With some sneaky coding, your *exact* picture can now be stored in one third or less the space as the original. Or modemed in one third the time or broadcast in one third the bandwidth. And you can reverse the process at any time to get your *exact* picture back.

The eye can resolve some things quite well, and others poorly. You simply do not see some details, and others are too subtle to worry about. By zeroing out several more of the remaining numbers, and by being crude about how accurately you code the rest of them, you could trade off picture quality versus compression.

And your changes in quality are progressive and subtle. Instead of picking up obvious "jaggies" as you reduce your picture's information content, you simply add broadband noise to it. Which is a much more pleasant and far less noticeable form of image degradation.

There are two papers on wavelet video compression that I've found both readable and useful. The first is

Application of Compactly Supported Wavelets to Image Compression from William Zettler and the rest of their crew at *Aware*.

Free single copies are available from them on request.

Secondly, while nearly anything on wavelets by John Daugman is a good choice, his *Entropy Reduction and Decorrelation in Visual Coding by Oriented Neural Receptive Fields*, in the *IEEE Transactions on Biomedical Engineering*, volume 36, number 1, January 1989, is outstanding.

Don't let the long title scare you away on this one. It is both a good intro to wavelet video compression and a look about how nature may be already using the wavelets to solve thorny visual problems and similar edge effects.

Should you want to explore the concept of histograms further, check out my HSTOGRAM.PS, available on *Genie* PSRT as file #146.

The Compression Shootout

All of which leads to an interesting dilemma. As we have seen in past issues and in the *Hardware Hacker III* reprints, the prewavelet all-time champion video squasher is called the

Discrete Cosine Transform. A crew known as the *Joint Photographic Experts Group* is in the final throes of making the *DCT* a standard.

You can pick up a reprint copy of the *JPEG Technical Standard, Rev. 8* through *Adobe Systems* if you want further details. This is a "must have" document if you are at all interested in video compression.

At any rate, an awful lot of people have spent an awful lot of time and money to make the DCT a major new video compression standard. And the PostScript Level II now has built-in DCT filters, and dozens of firms are offering or about to offer DCT compression solutions.

The only little problem here is that the wavelet transforms pass the DCT as if it was sitting up on blocks. It appears that anything that the DCT can transform, wavelets can do faster, cheaper, better, and with far fewer objectionable artifacts.

In particular, there are background "tiling" effects using the DCT, but none using wavelets. Your wavelet transform computations are quite simple, and much easier to realize in standard or near-standard hardware. Wavelets are also good at building up the "big lumps" first, followed by finer detail. This can get important in video animation.

So, I guess we are going to shortly see the answer to the question "What happens when a big bunch of people spend lots of time and effort creating a new standard which gets clearly and ludicrously obsolete before the ink on the final version is dry?"

Power Electronics Resources

Where can you go to pick up a replacement 3000 amp, 2000 volt SCR for your locomotive? The answers to questions like this one involve *power electronics*, a somewhat arcane and rather specialized backwater to the ongoing solid state revolution.

As our resource sidebar for this month, I've tried to gather together some sources for all the "Big Mutha" semiconductors and related parts. Stuff you might be getting into if you are now experimenting with those electric vehicles, any machine tool controls, the AC variable speed motor drives, welders, industrial controls, and similar high power goodies.

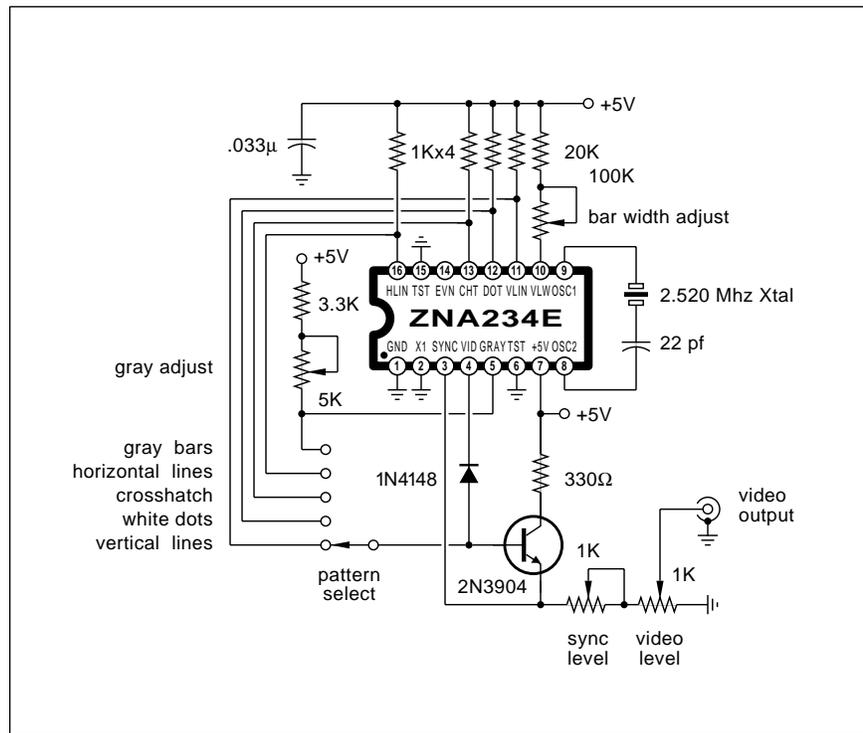


Fig. 5 – THIS MONOCHROME TV PATTERN GENERATOR uses the Plessey ZNA234E to generate sync, gray bars, lines, dots, and crosshatching.

An old line distributor by the name of *Galco* does seem to be the best one-stop source for most power semis. Their *Galco Gazette* is now free, while their 1500 page full line catalog is a refundable \$15.

Several of the many insider trade journals addressing power electronics include *PCIM*, *Motion*, *NASA Tech Briefs*, and *Motion Control*.

Hacker surplus power electronics seems catch-as-catch-can. But you can check *Fair Radio Sales*, *C&H Sales*, *Surplus Traders*, or else *Herbach and Rademan*.

Several of the more significant manufacturers of those higher power semiconductors and support products include *Asea Brown Bovari*, *Siemens*, *Powerex Inc.*, *Power Semiconductors*, *SGS*, *Plessey*, *International Rectifier*, *Motorola*, *Teccor*, and *Semikron*. Most of these have extensive data books and ap notes available.

A Dot and Bar Generator

Plessey Semiconductors has just revised a bunch of great data books, including their *Power Control IC Handbook* and their *Satellite Cable and TV IC Handbook*. This later gem is crammed full of all sorts of goodies ranging from infrared remote controls to teletext, synthesizers, and satellite downlink chips.

One of their other chips you may find of interest is their ZNA234E tv pattern generator. This chip generates monochrome video patterns including dots, vertical lines, horizontal lines, crosshatch, or gray scale and runs off a single +5 vdc supply.

Figure five shows a typical circuit. A crystal frequency of 2.520 Mhz is required for a 525 line NTSC output. An external RF modulator could be added for antenna-driven test needs.

This appears to be an older bipolar chip, since the supply current is an appallingly high 135 milliamperes. Yes, full interlace is provided.

New Tech Literature

A major new data book from *NEC Electronics* titled *Infrared Remote Control IC's*. And another one on *Voice Synthesis LSI* obtainable from *OKI Semiconductor*.

From *National Semiconductor*, a new *Guide to Video Products*. And for general low cost hacker hardware, a

POWER ELECTRONICS RESOURCES

Asea Brown Bovari 1460 Livingston Avenue N. Brunswick, NJ 08902 (201) 932-6000	Motion Box 6430 Orange, CA 92613 (714) 974-0200	Power Semiconductor 600 West John Street Hicksville, NY 11802 (516) 933-3000
C & H Sales 2176 East Colorado Blvd Pasadena, CA 91107 (213) 681-4925	Motion Control 800 Roosevelt SE-408 Glen Ellyn, IL 60137 (708) 469-3373	Semikron PO Box 66 Hudson, NH 03051 (603) 883-8102
Fair Radio Sales PO Box 1105 Lima, OH 45802 (419) 227-6573	Motorola 5005 East McDowell Phoenix, AZ 85008 (800) 441-2447	SGS 1000 East Bell Road Phoenix, AZ 85022 (602) 867-6259
Galco 26010 Pinehurst Drive Madison Heights, MI 48071 (800) 521-1615	NASA Tech Briefs 41 East 42nd St. #921 New York, NY 10017 (212) 490-3999	Siemens 2191 Laurelwood Road Santa Clara, CA 95054 (408) 980-4500
Herbach & Rademan 401 East Erie Avenue Philadelphia, PA 19134 (215) 426-1700	PCIM 2472 Eastman Avenue #33 Ventura, CA 93003 (805) 658-0933	Surplus Traders Winters Lane, Box 276 Alburg, VT 05440 (514) 739-9328
International Rectifier 233 Kansas Street El Segundo, CA 90245 (213) 772-2000	Powerex Hillis Street Youngwood, PA 15697 (412) 925-7272	Teccor Electronics 1801 Hurd Drive Irving, TX 75038 (214) 580-1515

1991 *Active Electronics* catalog.

One good source for Mac repair parts and good service information is *Soft Solutions*. And *Rolf Taylor* does offer Apple II repairs. Exchange parts for both families are available through *Shreve Systems*.

A new line of ultra high quality and fully professional RF ground plane breadboards is available from *RF Prototype Systems*.

For a rather unusual mechanical resource *Kindt-Collins* offers all sorts of industrial waxes, you can use for machining, CAD/CAM, moldmaking, investment casting, protection, and similar needs. Even water soluble waxes are offered.

A pair of wildly different ongoing hacker magazines that are going great guns are *Electro USA*, chock full of hands-on construction projects, many with a European or continental bent; and Jeff Duntemann's really great *PC Techniques*, an intense software and hardware computing resource.

Two newsletters of interest to any of you digital ham radio types include *Digital Digest* and *RTTY Journal*.

If you are at all interested in the PostScript language, do start out with my *LaserWriter Secrets* book & disk combo, Adobe's "blue" *PostScript Cookbook*, or their "red" *PostScript Reference Manual II*. All three are available through my *Synergetics*, or ordered via *GENIE* PSRT email.

We also now have the *Hardware Hacker III* and *Midnight Engineering I* reprints available, which have the latest and best of all these columns in them. All edited, revised, corrected, and indexed.

Finally, I do have a new and free mailer for you which includes dozens of insider hardware hacking secret resources. Write or call for info.

Our usual reminder here that most of the items mentioned appear either in the *Names and Numbers* appendix or in the *Power Electronics* sidebar.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8-5 in *Mountain Standard Time*, year round.

Let's hear from you. ♦

Don Lancaster's

Hardware Hacker

August, 1991

Electric power research info
Focused X-ray breakthrough
C-60 and the new Buckyballs
Getting telephone information
Caller number delivery secrets

Let us start off with several updates to the infrared people detectors we looked into a column or two ago. It seems *Amperex/Phillips* decided to jump ship and abandon their line of IR detectors. Their great ap notes seem to have been discontinued. Several remaining pyroelectric detector chip samples are supposed to still remain available through their (401) 762-3800 sales support line.

On the other hand, people detectors have instantly become a low cost commodity. So much so that it is now usually cheaper to buy retail and modify, rather than building your own motion sensor up from scratch. Especially when you factor in the critical *Fresnel* lens design. One big cause for the sudden price drop is a new California law which mandates these on nearly every light switch in new office building construction.

Herbach and Rademan offers a great and ready-to-install infrared people detector as #TM90SE1491 for \$12.50. And the *Heathkit* folks have several new occupancy and intrusion detector variations in their free home security electronics catalog. Or, you might also want to check your local price club or a warehouse builder's supply outlet.

A reminder that we have a great help line available for tech questions, off-the-wall networking, and useful consultant referrals. All per the box below. US callers only, please. And please remember that we are using California time during the summer. Those 4:30 am calls tend to get just a tad old. And please, please *carefully* read the *entire* column, especially the *Names and Numbers* sidebar.

Oh yeah. Please note the French mathematician's name is "Fern-ell", not "fresh-nell." And, of course, those correct pronunciations found on our ongoing voice helpline are "hee-lah" and "ten-ah-hah".

Our biggie for this month involves telephone caller identification chips and standards. But, first, let's find out how you go about...

Getting Telephone Information

Contrary to popular belief, it is real easy to get full technical details on nearly everything that involves the telephone company. All you have to do is ask them.

There is a great publication known as the *Bell System Technical Journal* that has been around for over 60 years now. Included are full details on just about everything involving telephone hardware and software. Check most any large technical library for your access. There's also the *Bell System Record*, but this one is nontechnical.

For ongoing telephone standards and tutorial info, start out with the no-charge *Bellcore 1991 Catalog of Technical Information*. Then order the individual papers you want. These do tend to be a tad on the pricey side, with \$20 to \$90 being typical. VISA orders are accepted with one week delivery. Sorry, but I don't know of any library that has a full set of these or loans them out.

Caller Number Delivery Secrets

Most of your telephone operating companies are now in the midst of upgrading to a totally digital system that includes a number of new CLASS services. By far the most popular new service is known as *Caller Number Delivery*, which can show you who is calling you before you pick up your telephone handset.

Caller number delivery does appear rather controversial. But, for most people most of the time, knowing

who is calling you is infinitely more important than protecting your "right" to make undetected obscene phone calls. Very sadly, at least one state (Pennsylvania) has stupidly banned this wonderful new service. In other areas, the caller is given the option of blocking their caller id, for those one-in-a-thousand calls when your anonymity might legitimately be desired. Maybe for a drug overdose hotline. Blocking can get done by entering a three digit code before you make your call.

So what is caller id, and how does it work?

Figure one shows you some of the more interesting Bellcore documents which involve caller id. But the key horse-mouth paper you'll need is Technical Reference TR-TSY-00030 and titled *SPCS Customer Premises Equipment Data Interface*. The cost is \$25 via VISA.

Figure two shows you the exact placement of the tone codes. Caller number delivery is normally provided as a code burst between the first and second *full* rings while your phone is still on its hook. Enough delay gets provided to allow for the short half second breaks sometimes involved in selective ringing.

After your first full ring gets detected, a data path is established. A data path is simply any method of receiving some modem tones. The id tones will then get routed to suitable circuitry to recognize the data burst and strip out the needed information. The format and codes are related to

1. NYNEX Catalog of Technical Information, #NIP-7400, Free.
2. SPCS Customer Premises Equipment Data Interface, #TR-TSY-0030, \$25.
3. CLASS Feature: Calling Number Delivery #FSD-02-1051, \$30.
4. CLASS Feature: Calling Number Delivery Blocking #TR-TSY-000391, \$33

The main Bellcore service number is (800) 521-CORE.
Of these resources, (2) is by far the most important.

Fig. 1 – HERE'S THE KEY INSIDER SECRET PAPERS involved with telephone system caller number delivery.

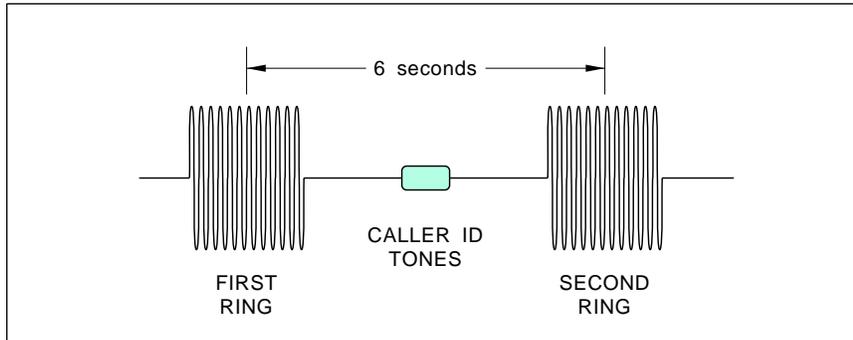


Fig. 2 – THE CALLER ID DATA BURST is sent between the first and second rings as shown. The transmitted level is -13 DBM and enough delay is provided to allow for distinctive ringing patterns. A typical number id will take half a second. The phone must remain on hook while the id is being received.

the digital codes used in pagers.

The tones sent out are plain old serial binary modem tones at 1200 baud. A digital logic one (or a *mark*) is defined as one cycle of a 1200 Hertz sine wave. A digital logic zero (or a *space*) is defined as nearly two cycles of a 2200 Hertz sine wave. Each eight bit character is preceded by a space start bit and a mark stop bit.

The transmitted signal level is -13.5 DBM. While the code transmission is asynchronous, phase coherence is preserved throughout the entire caller id message. No more than 20 marks are permitted between characters.

Figure three shows you the data format. Which might appear fairly complicated at first, but making sure

the number is valid is quite important. Almost certainly, you will elect to use a computer, or at the very least, some simple microcontroller in your caller id display circuitry.

The first thing sent is called the *channel seizure signal*. This consists of 30 bytes of a Hex \$55 code. After decoding, another way to look at this "hey wake up!" signal is one quarter second of a 600 hertz square wave.

After the channel seizure signal, a carrier signal is sent. This is used to condition your receiver for valid data. This carrier consists of at least 150 milliseconds worth of marks. After the decoding, you have a one-sixth second solid string of logical ones following your quarter second burst

squarewave at 600 Hertz.

Your caller-id receiver circuitry is supposed to use this "wake up call" and string of marks to prepare itself for valid data reception. After setup, the first valid data byte is called a *Message Type Word*. If this burst is for the caller number delivery, your message type word will be a hex \$04. Other codes could get used for other purposes. For instance, a hex \$0A means "message waiting" for pager applications.

The next byte is called the *message length word* and tells you how many digits are to be provided in the caller id numbers that are to follow. This message length does *not* include itself or the checksum in its count.

The actual ASCII characters for the caller phone number follow, starting with the least significant digit. For instance, a digit "2" should get ASCII coded as hex \$32.

Your message ends with a *checksum word* used for an optional error detection. The checksum is the two's complement of the 8-bit sum of the message type word, your message length word, and the number of data words provided. To provide an error detection, you run your own 8-bit sum of all the bits of all the data words, and then add the check sum to it. If there are no transmission or reception errors, you should get a zero result. A non-zero result means an irrecoverable error.

I've just described the *single data message format* to you. Some nasty complications can arise if you have multiple data messages or several CLASS services active, such as call waiting. See the Bellcore papers.

There are a number of caller id devices commercially available, with pricing in the \$60 to \$500 range. Typical are the *Allied incoming call identifier*, the *Bellsouth calling line identifier*, the *Cidco Slimline series*, and the TC-1021, TC-1080, and the TC-1082. One discount source of all these is *VSI Telecommunications*.

Do note that your caller number delivery service must be provided to you before you can use any of these devices. If the code is not being sent, there is no way you can receive it.

There might be certain state laws prohibiting their use as well. This, of course, can be cured by staking your

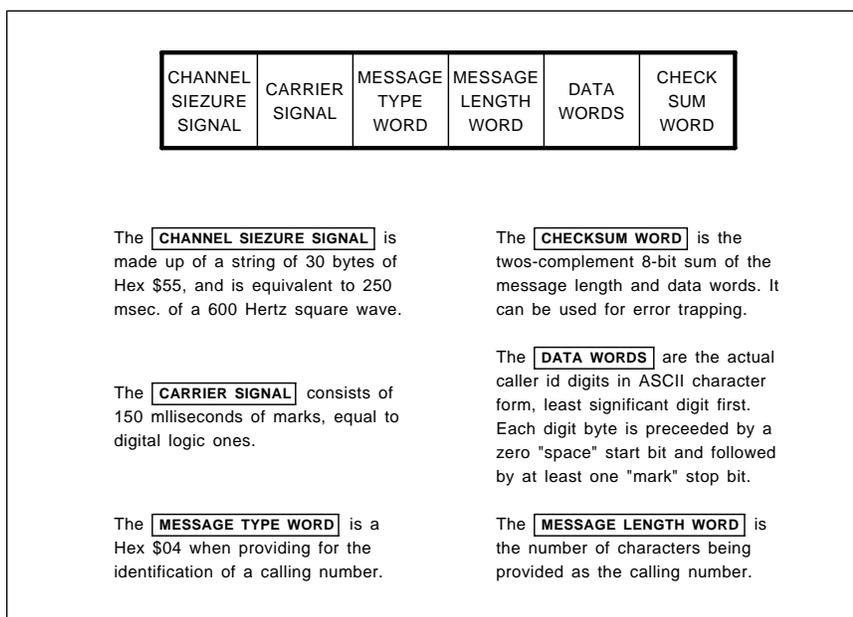


Fig. 3 – THE DATA FORMAT for the caller id service.

state representative to the nearest anthill. Finally, anything you connect to the telephone line has to be FCC Type 68 approved. Meeting the rules for type approval is fairly reasonable and simple. But the approval process itself is a bear.

We do have several experimental caller id projects in the works here at **Radio-Electronics**. Along with some simulator and test software. But there are ongoing problems with service availability, with meeting FCC part 68 specs, and in keeping the price low enough. Probably some absolute minimum general purpose caller id interface kit that *demand*s use of a personal computer programmed in machine language to develop your own circuits makes the most sense at this time.

A Caller ID Chip

As figure four shows us, there are usually four stages to the caller id receiver. The first stage is called a *FCC Part 68 Interface*. This one is needed to safely and legally connect to your phone system. Full details on Type 68 interface secrets appear in the *Hardware Hacker II* reprints.

The second stage forms the *analog front end*. The analog front end can provide filtering and amplification, and then converts all your tones into actual TTL ones and zeros.

Figure five shows you an analog front end circuit that uses the brand new *Sierra Semiconductor SC11211N* caller id chip. You input the low level telephone tones and get out a serial data stream ready for your computer or a microcontroller interpretation. Inside the chip is a fancy filter, an energy detector, a tone demodulator, and the clock. An ordinary tv color crystal and four capacitors is all you need to use this circuit. Cost for this 16-pin minidip is in the \$4 range.

There's also a fancier SC11210 chip in a smaller package that deletes the internal crystal oscillator, all the level setting, and the energy detection features. Sierra also has ap notes on suitable FCC part 68 interfaces.

While these chips are low in cost and work rather well, note that they are *only* analog front ends. "All" they do is reliably accept low level tones from the part 68 interface and then convert them into a string of digital

ones and zeros.

The third id stage is the *number extractor*. The number extractor can take your serial data stream, makes sure it is valid, and then extracts and formats your calling number. This number might also be displayed. The number extractor almost has to be a computer or microcontroller, since it probably would be unbearably complicated and expensive otherwise.

The final and optional stage is any "Gee Whiz" stuff. Things like looking up the actual name of the caller. Or pulling their sales or service records. Or keeping a full record of the last hundred calls. Or interacting with a humongus CD-ROM data base.

Once again, be sure to let us know what you want to see in the way of further caller id projects.

Buckyballs and C60

Carbon is one of the more interesting chemical elements. It forms the basis of all life as we know it. And, because of some energy and bonding restrictions, carbon quite possibly will also turn out to be the basis of all life as we don't know it. Carbon is also the key to most fuels, plastics,

and foods. It bonds readily with many other elements, creating by far the richest assortment of useful chemical compounds.

Until recently, there were only two known forms for any pure carbon molecules. These were the supersoft graphite and superhard diamond. But several chemists (Kroto, et al. *Nature* v318 p162 (1985)) have discovered a uniquely bizarre third form of carbon molecule. By taking 20 hexagonal groupings of six carbon atoms and then fusing them properly with 12 pentagonal groupings of five carbon atoms, a *hollow* geodetic pure carbon molecule of 60 atoms gets created.

Since this hollow all-carbon C-60 molecule looks like a geodetic dome or a socker ball, they were promptly given the name of *Buckyballs*, named after the late Buckminster Fuller, a leading early proponent of geodetic dome structures.

Initially a few C-60 molecules were painfully hand collected, measured, and tested. And, sure enough, C-60 is for real. An experimental proof of the Buckyball shape has recently shown up (Hawkins, *2Science*, v252, p312), along with a fine bibliography.

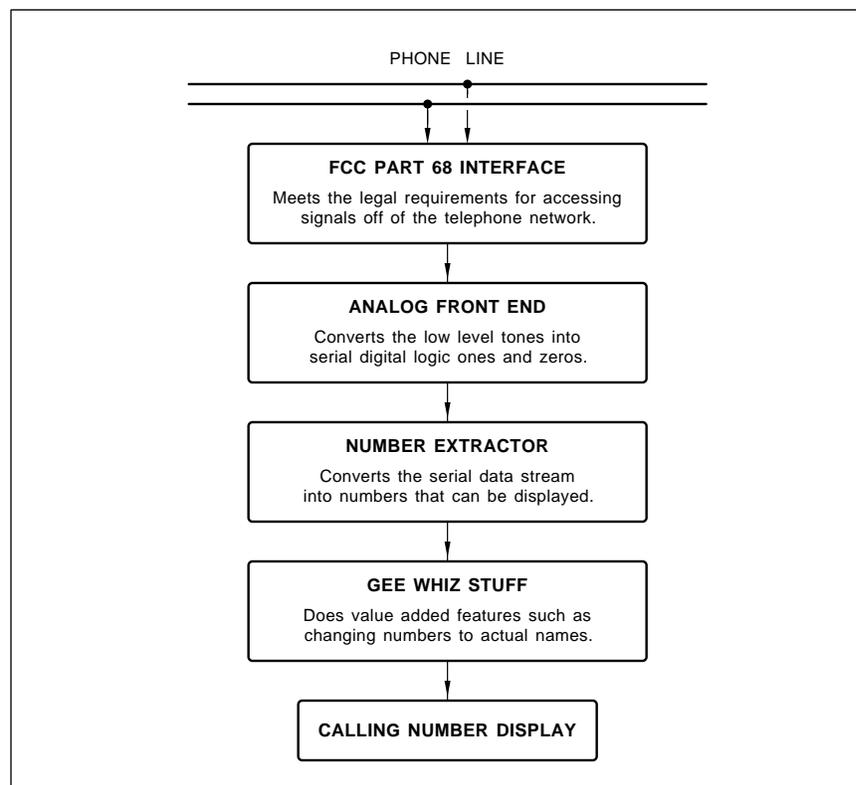


Fig. 4 – THE FOUR STAGES INVOLVED in a calling number id display.

After the discovery, several other chemists (Kratschmer, et al. *Nature* v347 on p354 (1990)) were playing around with carbon rods in a plain old arc welder and figured out how to make lots of Buckyballs in a process almost as complicated as smoking a piece of glass with a candle.

As a result, the price of Buckyballs has plummeted to an astonishingly low \$1200 per gram. Quantity pricing is even less, and 100 milligrams of Buckyballs are available for \$250 if you are on a limited budget. You can get all the Buckyballs you want off the shelf from *Materials and Electrochemical Research*.

The latest games include putting Osmium "handles" on a Buckyball to make them easier to align, and adding precise doping impurities to create several new families of "Dopeyballs".

While nobody has yet come up with a proven commercial use for Buckyballs, they are now by far the hottest topic in physical chemistry. Buckyballs will even superconduct, although only at rather low temperatures so far. The hollow molecule suggests all sorts of stunning new possibilities which include super lubricants, new batteries, ultra-strong fibers, improved semiconductors, and entire new classes of materials and compounds.

Needless to say, Buckyballs are a sure fire winner for a Science Fair topic or school research paper. And we here at **Radio-Electronics** would

certainly be most interested in any Buckyball project which was even remotely related to electronics. Let us know what you can do here.

Ongoing info on Buckyballs will appear in those *Science* and *Nature* magazines, and, of course, through the *Dialog Information System*.

Electric Power Research Institute

EPRI is a rather low key research consortium. You have to be a power company to join them. Even then, their annual membership fees are astronomical. But, with their \$400 million annual budget they now do all sorts of top quality energy research, including thorough coverage of such subjects as solar power, efficient lighting, cogeneration, conservation, environmental quality, cold fusion, and alternate energy sources. Plus, of course, nasty old nuke stuff.

EPRI does have plenty of videos, technical reports, papers and such available. They also have products for licensing. The summary report of most of their recent key papers costs \$45. You might like to contact them directly for further info.

New Tech Literature

A new method of focusing X-rays known as a *Kumhakov lens* is now described on page 208 of *Science* volume 252. If it proves as good as it looks, this could revolutionize everything from high density integrated circuits to safer dentistry. The lens

consists of scads of glass capillaries, and the X-rays skip along the surfaces at low angles, rather than shooting right on through them.

From *National Semiconductor*, a new *General Purpose Linear Devices* data book. And from *SGS-Thomson* a new *Power Transistors Application Manual*. Good stuff.

Satco is a great source for oddball tools and supplies. They usually sell to those school vocational education programs. They do have a great new thousand page catalog available.

Unusual scientific images of all sorts of geologic, oceanographic and atmospheric stuff is available on a GRIPS-2 CD-ROM from *Meridian Data*. It is part of a new program to release obscure government research to a wider audience.

Our unusual trade journal of the month is *Power Quality*, aimed at the higher end users of uninterrupted power supplies.

Chip capacitors and resistors for surface mounting are now finally becoming widely available in small quantities at sane pricing. While *Mouser Electronics* is a good source, some ready-to-go \$49.95 resistor and capacitor kits are available through *Communications Specialists*. That's three cents each for the resistors and fourteen for the caps.

Turning to my own products, for the fundamentals of digital integrated circuits, do check out my *TTL Cookbook* and *CMOS Cookbook*. Or you can pick up all of those "oldies but goodies" all at once in my *Lancaster Classics Library*.

I also do have a BBS up as *Genie PSRT*. Besides all the PostScript and desktop publishing stuff, you'll find all sorts of ongoing *Hardware Hacker* and *Midnight Engineering* resources here. You can get your voice connect info by dialing (800) 638-9636.

We also now have the *Hardware Hacker III*, *Ask the Guru III*, and the new *Midnight Engineering I* reprints available, which have the latest and best of all these columns in them. All edited, revised, and indexed.

I do have a new and free mailer for you which includes dozens of insider hardware hacking secret resources.

Our usual reminder here that most of the items mentioned appear in the *Names and Numbers* sidebar. ♦

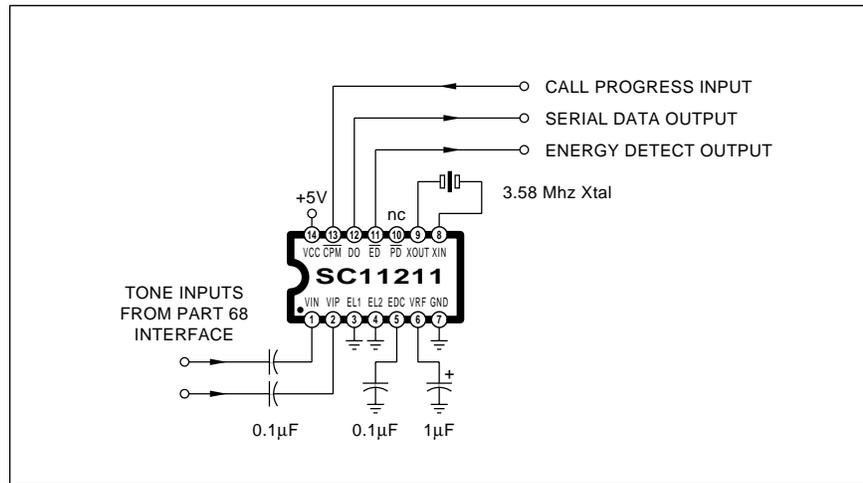


Fig. 5 – A CALLER ID ANALOG FRONT END that makes use of the Sierra Semiconductor SC11211 chip. Low level tones are accepted from the FCC Part 68 interface and get converted into serial ones and zeros for further digital processing.

Don Lancaster's

Hardware Hacker

September, 1991

Driving inductive loads
More on phone caller ID
Bakerizing and laminating
Alternators as stepper motors
Programmable logic resources

Let us first pick up on several updates to some of our earlier *Hardware Hacker* topics. One good source for those BA1404 FM stereo broadcasting kits is *DC Electronics*. They also stock the super new *Signetics* NE602 mixer/converter chips and the TEC-200 film for direct toner printed circuits. Another NE602 source is *Active Electronics*.

Telephone caller ID is certainly one hot topic these days. And yet another source of call identifier magic boxes is *Hello Direct*. Prices start at \$60. You must, of course, have the IDservice available before you can use these magic boxes. States that have at least some local availability of caller ID should now include AL, CA, FL, GA, IL, IN, MD, ME, MI, NC, NE, NJ, NV, OH, OK, SC, TN, VA, VT, WV, and Washington DC. Other areas are still in the planning stages. Most services are still for local calls only.

One handy and rather non-obvious benefit of this new service: When you come back from lunch, you have a complete and a time stamped list of everyone who tried to call you when you were out. Most useful.

I thought we might round up a big collection of odds and ends for this month's column...

Driving Inductive Loads

If you blindly connect a transistor or another solid state device to an inductor such as a relay or a motor coil, you will almost certainly blow out your circuit the very first time you try to power it up. Special protection techniques are *always* needed when you try to control an inductor's current with any solid state device.

These inductive circuit protection techniques are cheap and simple, but you do have to understand what is coming down to use them properly.

Take a coil of wire and connect it to your voltmeter. Now shove a magnet through the center of your coil. As you insert the magnet, you generate a positive induction voltage. Remove the magnet, and you'll generate a negative induction voltage. Any time

your magnetic field *changes*, you'll generate an induced voltage. And the faster the change, the more voltage you create.

Since any current through a coil can generate a magnetic field, any change in your coil current should produce a change in the magnetic field, which in turn will induce a voltage spike. The greater or the more sudden the change in the current, the greater the induced voltage.

The basic math here says that...

$$e = L \Delta i / \Delta t$$

or, in English, your induced voltage across any coil is proportional to the size of the inductor and the *rate of change of current through the coil*.

Say you decide to control a relay. You turn your relay on by sending a current through your coil. And then you attempt to turn your relay off by suddenly disconnecting your coil current. What happens?

Your magnetic field will suddenly collapse, generating a horrendous voltage spike. You tried to make Δt zero, and, since you're now trying to divide by zero, you get a theoretically *infinite* voltage spike.

Thus, *suddenly ceasing the current in any inductance is guaranteed to create a humongous voltage spike*.

Sometimes you might choose to purposely do this. For instance, the current through the coil in any car ignition is suddenly broken to step up the 12 volt battery into many tens of thousands of volts of ignition spark voltage. And a related technique gets used for television high voltage.

But, should you suddenly cease a current through any coil in any solid state circuit, the voltage spike you'll get is almost certain to blow up the transistor of whatever happens to be controlling your coil.

The rule here is simple: *Never let the current through an inductive load suddenly drop to zero in any solid state circuit!*

Figure one shows you how to add a plain old power spike protection. Note

that the diode appears "backward" so that it does *not* normally conduct any supply current.

If you suddenly try to turn off the inductor current, a small induced voltage will immediately be created that in turn forward biases and turns on the protection diode. *The current you had before can then continue on through your protection diode and back into the relay coil*. The current will now drop on down to zero fairly quickly, dissipating itself in the forward drop of the diode and in the internal resistance of your relay coil. At no time is any voltage spike generated that exceeds the 0.6 volts or so of your diode forward drop.

This simple diode despiker works quite well. But there are some minor side effects that can sometimes cause problems. Note that your relay will *stay* pulled in for a brief time delay after you thought you turned it off. This happens because there is still diode-provided current going through your coil. In a larger relay, this time delay could extend a few tenths of a second, and could cause you timing problems.

The physical dropout of your relay can also end up slower and sloppier. Which could cause contact arcing in

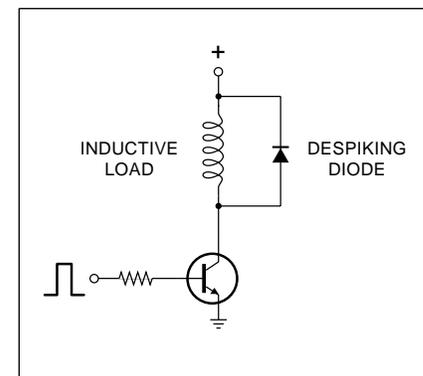


Fig. 1 – ANY SEMICONDUCTOR can be instantly destroyed if you use it to suddenly turn off the current in an inductive load. The despiking diode shown here allows the coil current to continue long enough to safely dump all the magnetic flux energy without creating a killer transient.

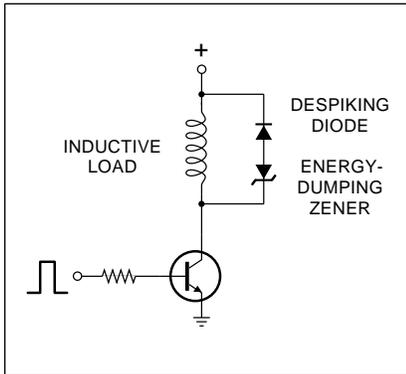


Fig. 2 – A SERIES ZENER diode shortens and sharpens the dropout time. This minimizes turn-off delay and contact arcing in power relays. Your control transistor must be able to block the supply voltage PLUS the zener voltage.

higher current applications.

Your protection diode also should turn on fairly fast. If you use a slow diode or if there is not enough stray circuit capacitance around, a large and possibly destructive spike can build up during the time your diode actually starts conducting.

Figure two shows you an improved spike protection circuit. Here we have added a 24 volt zener diode in series with your protection diode. This combination will conduct no current in one direction and will conduct in the other direction only when the voltage across it exceeds the zener breakdown of 24 volts. You could think of this series

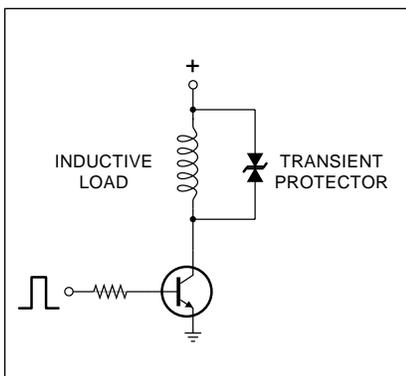


Fig. 3 – ELECTRONIC TRANSIENT suppressors are bidirectional devices which are also known as varistors, MOV's, TRANSILS, or several other trade names. These have to be very carefully matched to the allowable voltage rise and the magnetic flux energy to be dumped.

combo as an "inefficient diode" with a 24 volt forward drop.

Whenever you suddenly disconnect your relay current, a large but acceptable 24 volt high voltage spike is created, which turns on both diodes in the series pair. The current continues through the diodes, but will fall to zero *much* faster as you now have a 24 volt drop burning up much of your remaining coil energy.

Thus, this circuit will still give you protection, but will shorten the excess holding time by a factor of 40 or so. Your contact release will also be that much faster.

What happens is that you've now made a tradeoff. You are allowing a reasonable sized spike in exchange for a large reduction of the release time. Note that your transistor will see a maximum voltage of your supply voltage *plus* the drop of that zener during break time. For instance, on a 12 volt supply, your transistor would have to block at least 36 volts if it is not to be damaged.

There are special back-to-back Zener-like components intended for spike protection. These go by the names of *varistors*, *MOV's*, or *transient protectors* and do have various brand names. They work the same way as figure two in that they do not conduct until spike time. Then they do conduct heavily and thus internally dissipate the inductor's flux energy. Figure three is a typical circuit.

SGS is one of many suppliers of the *TRANSIL* spike protectors. Their BZW04P23 is typical. At 25 volts or under, it draws only five microamps. Above 30 volts it starts conducting heavily, and by 41.5 volts it draws at least ten amperes. Despite the tiny package, these devices can stand fifty amps for ten milliseconds. Higher power units are also available.

You will have to carefully match your protection device to the size of the spike you are willing to allow and the amount of energy that you need to dump from your coil.

If at all possible, you should also isolate your coil drivers from more sensitive parts of your circuit. Optoisolators and individual power supplies are great for this.

More info on spike protection and computer interfacing appears in my *Micro Cookbook*, volume II.

Car Alternators as Stepper Motors?

A *stepper motor* differs from an ordinary motor in that it can deliver incremental motion in the form of tiny precise steps, instead of doing a continuous rotation. The important advantages of a stepper motor are the precision with which you can set an output shaft position, the ability to rapidly and conveniently change the direction or the speed of your output steps, and the capability of strongly holding a zero speed position.

Small stepping motors are widely used for such things as printer paper feeds, automobile idle controls, pen plotters, and sometimes for disk drive head positioners. And most any old surplus electronics catalog will have lots of of small steppers and all their drivers cheaply available.

But what about the heavy stuff?

There are lots of good hacking uses for power stepper motors. Obvious examples include robotics, machine tool power feeds, animation stands, plotters, sign cutters, solar pumps, and even Santa Claus machines. As you have probably noticed by now, power stepper motors are rare, horrendously expensive, hard to get, and harder to drive. Did I mention being hot and noisy power hogs?

An industrial arts teacher out of Phoenix by the name of Bob Knight stopped in the other day with what just might be a brilliant hack.

Junkyard car alternators cost under \$5 each, especially if you don't particularly care which model you are getting. Can you convert an alternator into a power stepper?

The needed mods do appear to be simple and obvious. Power FET or Darlington drivers are not that big a deal these days.

My first response was "yes, but...", and I immediately came up with a dozen good reasons why this flat out would not work. At least not very well. Things like a wide air gap, low frequency mechanical resonances, dc biasing, giant step sizes, all the non-optimum magnetic paths, very poor damping, backlash, slow speeds, and an efficiency that probably would be an outright joke.

On the other hand, if you pulse an alternator, there is no way you can

hold onto it when you do. The kick is definitely there.

At best, I would guess that you could not get as much useful force with a car alternator than you can by using a much smaller "real" stepper motor. And the alternator would end up ridiculously slower to boot.

I'd like you to try and prove me wrong. Either as this month's contest or for a winning school lab project, experiment with a car alternator and find out exactly how useful a power stepper motor you could convert it into. Could you in fact create a \$5 machine tool power feed with one?

How fast can you go? How much output force can you get? How good are the steps? What is the best computer interface?

There'll be the dozen or so of our usual *Incredible Secret Money Machine* book prizes, along with a big all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.

OK. Figure four shows you some conversion hints.

Most real stepper motors do use a permanent magnet rotor. With an alternator, you would use this field winding and slip rings for a giant electromagnet, running as much current through it as you can without overheating. This forms a group of seven shaft attached magnets that you can rotate to a desired position by activating the stator coils.

And speaking of which, there are normally three sets of stator coils. These are usually hooked up in what is known as a three-phase wye circuit. For stepper use, you will want to find the floating splice where your wye connection is made and bring it out as a separate positive terminal. Which should then give you three distinct and independent winding sets.

Let's call the windings A, B, and C. Power the field via the slip rings, and pulse winding A. Keep your current down around an amp or two at first to prevent any overheating or driver problems. The rotor will align itself with the nearest pole piece and should lock itself to some position. Now turn off winding A and activate winding B. The rotor should now jump one step clockwise. Turn off B and whap C. And you should jump yet another step clockwise.

To step on clockwise, use an ABC sequence. To step counterclockwise, just use ACB instead. You'll probably want to keep at least one winding energized at all times so that you can hold a position when not stepping.

Note that you could end up in position A, B, or C, depending on the power sequence. You will have to remember where you are with your controller or host computer. A typical alternator should give you 21 possible positions, and a resultant step angle of around seventeen degrees.

You would disconnect all of the alternator diodes during your conversion. These could later get used as protection diodes serving the driver circuits if you do not have anything better available.

One hint: Your slip ring brushes can "explode" whenever you take any alternator apart. And the two brush springs will fly off into the hinterlands. Look closely, and you'll find a toothpick size hole in the insulated brush holders. To reassemble, you just put a toothpick or a stiff wire through

the hole to hold the brush springs compressed. Done just right, you should be able to remove the toothpick from the alternator outside after you do your reassembly.

The rotor winding of an alternator is a fairly high resistance, usually around 5 ohms or so. It will safely current limit itself. But your stator windings are an extremely low impedance, typically under a quarter ohm. Thus, you *must* externally limit your rotor currents to keep things from burning up. Plain old power resistors are a good way to handle this for your early experiments.

There are some tricks you could pull to improve the number of steps per revolution. One would be to allow two windings to be active at once. This could double your resolution.

A fancier technique would be to allow several different values of the current for each winding. This leads to various new *microstepping* opportunities. Microstepping is a proven concept with real stepper motors.

Yet another possibility is to use a

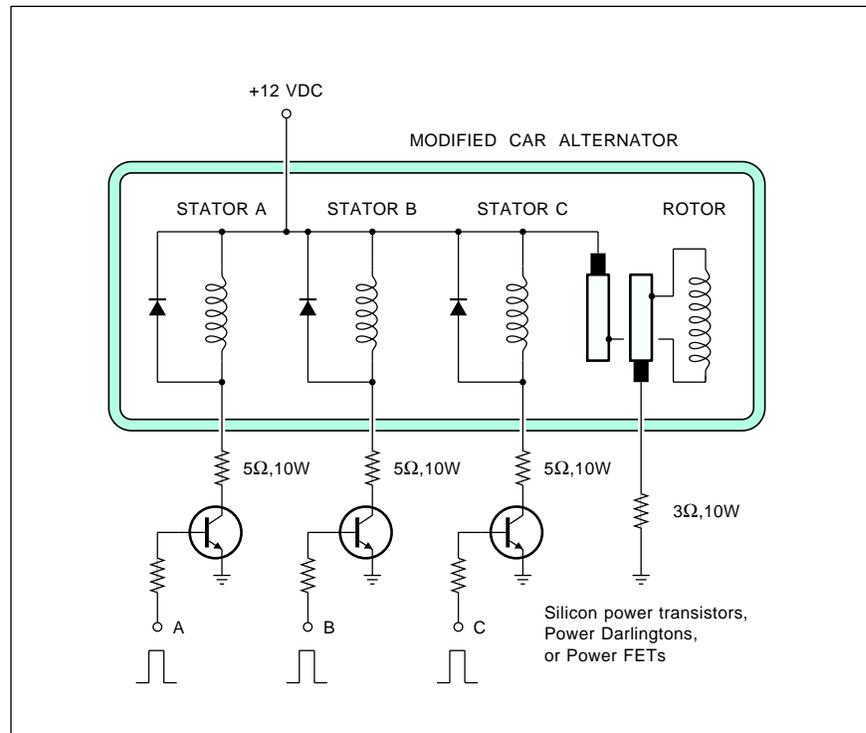


Fig. 4 – CAN A CAR ALTERNATOR get converted into a \$5 power stepper for a machine tool drive? Only hackers know for sure. To experiment, use the rotor as a powered electromagnet. Find the floating stator wye connection and bring it out as a power terminal. Pulse one stator winding at a time in an ABC (clockwise) or an ACB (counterclockwise) sequence. Be sure to safely limit stator currents. Especially for all of your initial tests.

bridge type drive which lets you run current either way through any given winding. You could now use both attraction and repulsion, and, once again, should be able to double the number of steps.

And one final resolution enhancer would be to put a nutplate of some sort on the shaft end, creating a *linear stepper*. A threaded shaft through the nutplate will then move forward or backward as the alternator steps.

For instance, with a 1/4-20 thread, each full revolution would advance you fifty mils. One single step at 21 steps per revolution would advance you a mere 2.38 mils, besides giving you a really major mechanical advantage to boot.

Simple gearing could also be used to increase your step resolution. But you'll have to watch out for backlash if you attempt this. And do note that the finer the resolution, the slower your max allowable operating speed. Sorry about that.

You might also like to look at some *dual current* scheme that gives you a brief high current pulse when stepping and some lower holding current between the actual steps.

After you really have your stepper working reasonably well, you'll want

to increase all the operating currents. Overheating, saturation effects, and overshoots set your ultimate limit.

It might also be very interesting to rewind all your stator coils. Use lots more turns of a much smaller diameter wire, and try bridging only a single stator pole rather than three. Ampere turns is the name of the game here. You could also try improving the rotor flux paths and air gaps.

For further resources on power stepping in general, check out *Airpax* and *Slo-Syn* for iron, the *PCIM* and *Motion* trade journals for info, or *SGS*, *Sprague*, or else *Motorola* for useful drivers. One distributor that stocks a wide selection of power electronics stuff is *Galco*. And good old *J.C. Whitney* has bunches of alternators and parts available, including some rewind 100 amp stators that go for around \$18.

You will find lots more on power electronics in our brand new *Hardware Hacker III* reprints.

There's lots of possibilities here. Let's see what you can come up with.

Programmable Logic Resources

Besides all those good old hacker EPROM's, we now do have dozens of variations on low cost you-program

integrated circuits. Some (such as EPROMs) are based on exhaustive table lookups. While others (such as PLAs) do multilevel AND-OR digital logic using combinations of gates and registers for their logic.

Some are one-shot programmed by blowing fuses. Others are easily re-programmable. And yet others use a *flash* technology where the needed connections can get saved to a non-volatile RAM memory during power down times.

The prices of some programmable chips are now down in the \$2 range. The important advantages of these new devices are that you can place the exact circuit you want into one or two packages; that they are easy to debug and modify yourself; that some can recalibrate or update themselves later on in-circuit; and that you are (at least temporarily) the sole source of your "secret" inside programming connections. All with instant delivery and no staggering setup charges.

I've tried to gather together some of the more popular programmable logic suppliers into this month's resource sidebar. You might want to get data books and individual ap notes from many of these sources.

One side note that is both alarming and sad. Many of these houses refuse to divulge the key programming info needed to use all their chips. While I consider this a monumentally stupid way to cut off your nose to spite your face, their argument is that they most definitely do want you to use some "approved" programmer that is more likely to keep their products reliable in any final use circuits.

Here's a trick that *may* help you get programming info should reasonable and direct tries fail. The magic new buzzword in chip programmers these days is "DAC per pin". Just tell those application engineering people that you're now about to ship production quantities of your new pc-based DAC-per-pin programmer, and that you would like to be able to include programmability for their chips.

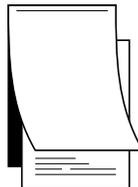
Our helpline has been full of horror stories on programming info, but this ploy seems to work so far. At least till they catch on.

Please do continue to send in your horror stories on this topic.

More details on the use of EPROMs

BAKERIZING

With BAKERIZING, your toner image is temporarily placed in close contact with a smooth film. Heat and pressure is then applied. The toner becomes much blacker and takes on a beautiful medium to high gloss. Some films can be reused.



LAMINATING

With LAMINATING, a thin clear plastic overlay is permanently attached to your copy by using heat and pressure. This process seems ideal for menus and book covers, or where extreme scuff resistance to "lock in" your toner is required.

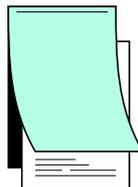


Fig. 5 – THESE TWO "MAGIC" FILMS can dramatically improve both the appearance and durability of any toner image.

appears in my *CMOS Cookbook* and *TTL Cookbook*, while the listings in our resource sidebar and all the usual trade journals should also have lots of application info.

Bakerizing Secrets

Despite my screaming it from the rooftops for quite a few years now, Bakerizing seems to remain a top secret procedure. Which amazes me because anyone that sees what this process does is absolutely stunned.

Bakerizing is a sneaky trick you can apply to most any laser toner image, especially all of your PostScript laser printed output. Bakerizing instantly makes toner a high gloss jet black, while at the same time dramatically increasing the durability and crease resistance.

While excellent for business cards, Bakerizing works nearly anywhere you want a blacker and denser image. And the process is nearly free!

All you have to do to Bakerize is take a sheet of special high gloss, slip coated polyester film. You then temporarily place this film in contact with your toner image and then apply heat and pressure. This remelts your toner while contacting a mirror smooth surface. Which then can produce a *calandering* process similar to that ferrotype drum on older darkroom glossy print processors.

The simplest way to Bakerize is to put the magic sheet on top of your hard copy and shove it back through your printer while imaging a blank page. The best way to Bakerize is to use a *Kroy Color* or *Canon* fuser unit or some sort of laminating machine. But even a plain old iron can sometimes be used effectively.

With care, any single Bakerizing sheet can be reused dozens of times. Which can drop your per page costs to a few pennies per copy.

I have gone ahead and custom ordered a zillion sheets of Bakerizing film and will be offering it as a stock product here at *Synergetics*. I've also now got some more traditional yet toner compatible laminating materials suitable for nice looking menus and book covers. Figure five shows you how these two films differ.

Give me a call if you want to play with either of these really exciting new materials.

PROGRAMMABLE LOGIC RESOURCES

Actel 955 East Arques Avenue Sunnyvale, CA 94086 (800) 227-1817, ext. 60	Intl. CMOS Technology 2125 Lundy Avenue San Jose, CA 95134 (408) 434-0678	Raytheon 350 Ellis Street Mountain View, CA 94039 (415) 962-7930
Altera 2610 Orchard Parkway San Jose, CA 95134 (800) 800-EPLD	Intel 1000 Business Ctr Drive Mt. Prospect, IL 60056 (800) 548-4725	Texas Instruments PO Box 117692 Carrollton, TX 75011 (800) 336-5236, ext. 3707
Advanced Micro Devices PO Box 3453 Sunnyvale, CA 94088 (800) 222-9323	Lattice Semiconductor 5555 NE Moore Court Hillsboro, OR 97124 (800) FAST-GAL	Toshiba 1220 Midas Way Sunnyvale, CA 94086 (800) 321-1718
Catalyst 2231 Calle de Luna Santa Clara, CA 95054 (408) 748-7700	Mitsubishi 1050 East Arques Avenue Sunnyvale, CA 94086 (408) 730-5900, ext. 2106	Waferscale Integration PO Box 117692 Fremont, CA 94538 (415) 656-5400
Cypress Semiconductor 3901 North First Street San Jose, CA 95134 (800) 952-6300 Dept. C4P	National Semiconductor 2900 Semiconductor Drive Santa Clara, CA 95051 (800) 272-9959, ext. 40	Xicor 1511 Buckeye Drive Milpitas, CA 95035 (408) 432-8888
Fujitsu 3545 North First Street San Jose, CA 95134 (800) 642-7616	NEC Corporation 401 Ellis Street Mtn. View, CA 94039 (415) 965-6000	Xilinx 2100 Logic Drive San Jose, CA 95124 (408) 879-5199
Gould AMI 2300 Buckskin Road Pocatello, ID 83201 (208) 234-6668	GEC Plessey 13900 Alton Pkwy S123 Irvine, CA 92718 (800) 927-2772	

New Tech Lit

From *SGS*, the new *Shortform 91* catalog that is especially strong in automotive, telephone, VCR and consumer audio chips. From *Rochester Electronics*, a 1991 Catalog. They do specialize in stocking out of date and discontinued semiconductors.

A free design guide and catalog on *Solar Electric Power Systems* through *Photocomm Inc.* And the latest free volume of that *Maxim Engineering Journal* has all sorts of goodies in it on efficient regulators, digital filters, and other innovative new chips.

Two trade journals for this month do include *Memory Card Systems & Design* on the new RAM and EPROM memory cards used for laptops and whatever; and *Trade Winners*. The latter is sort of a Hong Kong version of *Computer Shopper* that can give you direct access to many Far East electronic manufacturers.

Let's see. I've just reprinted my *Incredible Secret Money Machine II*, along with its new intro and update section. And we are now Book-on-demand publishing our *Hardware Hacker III*, *Ask the Guru III* and my *Midnight Engineering I* reprints.

A reminder about my new BBS up as *GENIE PSRT*. Besides all of that PostScript and desktop publishing stuff, you'll find all sorts of ongoing *Hardware Hacker* and our *Midnight Engineering* resources here. You can get your voice connect info by dialing (800) 638-9636.

Finally, I do have a pair of new and free mailers for you. One includes dozens of insider hardware hacking secret resources, while the other is on PostScript and Desktop Publishing. Write or call for info.

As usual, most of the items mentioned here appear in the *Names and Numbers* appendix or in the *Programmable Logic Resources* sidebars. ♦

Don Lancaster's

Hardware Hacker

October, 1991

Curve fitting fuzzy data
Tesla Coils and resources
Meeting FCC regulations
Flashlight battery supplies
Thoughts on E field machines

Just how could you go about meeting FCC specs? Contrary to common belief, the Federal Communications Commission regs are very easy to find and are not really all that expensive.

Most federal regulations appear in the humongous group of paperback volumes known as the CFR and short for their *Code of Federal Regulations*. Each government bureaucracy has their own *title* in the CFR series.

For instance, their *title 14* is for Aeronautics and Space and *title 37* is the Patent and Trademark office. Of our interest here, *title 47* is the FCC regulations that govern any use of radio spectrum space, intentional or otherwise.

You can view most CFR volumes in most any large library that has a government documents section. The volumes are also now conveniently available from the *US Government Bookstore*. Yes, VISA and MC are accepted, with one week delivery.

The FCC regulations are organized into a hundred separate *parts*. Figure one shows you the more popular parts for topics of any hardware hacking interest. For instance, computers and peripherals have to follow part 15. Telephone interconnection has to obey part 68. Citizens band is part 95, and amateur radio is part 97. And those new direct broadcasting satellites are now part 100.

There are five volumes in the title 47 series, whose costs range from \$10 to \$20 each. These are arranged as parts 0-19, parts 20-39, parts 40-69, parts 70-79, and parts 80-102.

Typical charges for a registration, certification, or a type approval are usually in the \$300 to \$1500 range, depending on whether any testing is needed. More details on fees appear in parts zero and one.

Meeting FCC specs on your own can be monumentally frustrating and be horrendously expensive. Besides taking forever. There are specialists who are willing to help you for a fee. The foremost trade journal for this is called *Compliance Engineering*.

Tesla Coils and High Energy Resources

Nikola Tesla was certainly one of the greatest hardware hackers of all time. To this day, his developments of polyphase power distribution and the ac induction motor remain the very center of electrical engineering.

Despite these stunning achievements, Tesla is probably more famous today for his work with *Tesla Coils*. Basically a higher frequency transformer used to generate spectacularly high voltages. Voltages that can literally stand people's hair on end.

On the other hand, Tesla was a lousy theoretician, and most of his explanations of just *why* his devices worked often ended up as flat out wrong. Particularly when it came to recognizing the obvious differences between resonant energy *storage* and actual net power *generation*.

Sadly, there have been heaping bunches of mythology and plenty of outright hogwash that seems to have

built up around Tesla. After years of careful reading, I have yet to find even the slightest credible shred of evidence that (A) Tesla was an extra-terrestrial alien, (B) Tesla invented a unique free energy perpetual motion machine, or that (C) All Tesla's *real* inventions got suppressed by a paranoid government conspiracy.

For our resource sidebar for this month, I've tried to gather together some of the more useful sources of accurate materials and information on both Tesla and Tesla Coils.

Try the *Tesla Book Company* for a well done collection on books and publications on and about Tesla that range the gamut from historical fact on down through utterly absurd few-chips-shy-of-a-full-board fantasy.

Lindsay Publications also stocks some of the better and more factual titles, as does *Industrial Micro*.

One leading supplier for museum quality Tesla systems is *Resonance Research*. Their *Modern Resonance Transformer Design Theory* book is a

Part 0	Structure and organization of the FCC.
Part 1	Rules, fees, certification, type approval.
Part 2	Frequency spectrum allocations.
Part 5	Experimental radio services.
Part 13	Commercial radio operations.
Part 15	Radio frequency devices (includes computers, peripherals).
Part 18	Industrial and medical equipment.
Part 21	Public service fixed communications.
Part 22	Public service mobile communications.
Part 23	Shortwave broadcasting.
Part 25	Satellite communications.
Part 68	Telephone terminal equipment.
Part 73	AM and FM broadcasting.
Part 74	Auxiliary AM and FM broadcasting links.
Part 78	CATV cable television.
Part 80	Maritime and shipping communications.
Part 87	Aviation communications.
Part 90	Private mobile services.
Part 94	Microwave relay.
Part 95	Personal and CB citizens bands.
Part 97	Amateur radio.
Part 99	Disaster and emergencies.
Part 100	DBS Direct broadcast satellites.

Fig. 1 – FEDERAL COMMUNICATIONS COMMISSION regulations are presented in title 47 of the Code of Federal Regulations. Here are how the more useful and popular parts are arranged.

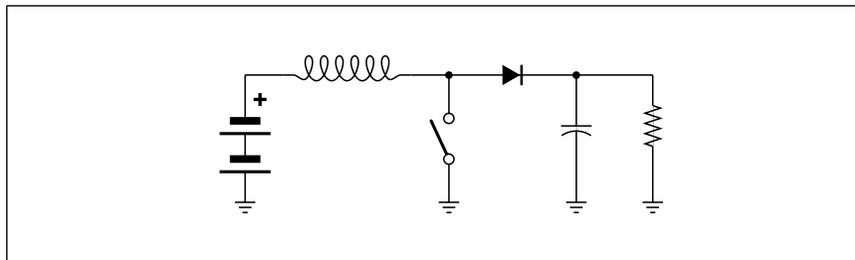


Fig. 2 – THE SWITCHING MODE STEP-UP CONVERTER. Briefly but repetitively closing the switch causes the current in the inductor to ramp up to a high value. On release, the high current is transferred to the load resistor, appearing as a voltage that is always higher than the input. The switching duty cycle sets the amount of voltage step-up you will get.

classic, and they do offer interesting design software and videos.

Good sources for Tesla Coil parts include *Edmund Scientific*, *JerryCo* (now renamed *American Science and Surplus*), and *Surplus Traders*. One newsletter that has lots of hands-on low end Tesla info in it is *Tec-Spec*. One interesting hacker club is that *Tesla Coil Builder's Association*.

At one time before the personal computer revolution, building a Tesla coil for a Science Fair was a required rite of passage for any Hardware Hacker. Although these induction coils still can be spectacular and lots of fun, they are really nothing but an oversize auto ignition coil or a tv flyback transformer.

Outside of the science museums, induction coils just aren't that big a deal any more. Not to mention the incredible radio and television in-

terference that a sloppily done Tesla coil generates. Or the X-ray danger.

Is there any point in hacking ultra high voltages? Typical electrical (or "E") fields have a magnetic (or "H") field associated with them. In theory, you could build up your motors and generators using only the electric field, using only the magnetic field, or using any combination of the two. But look around you, and you'll find just about every common motor or generator is a magnetic one that uses the H field nearly exclusively. The only obvious exceptions that prove the rule are such nanopower niche items as piezo fans.

Most previous hackers who have explored the E field have now found electric field machinery to turn out extremely large, besides having unacceptably low power densities and even lower efficiencies. To this day,

creating the insulation materials, the surface treatments, and the vacuum needed to support ultra strong E fields remains a very thorny problem.

On the other hand, for free energy, all you need is an insulated stationary vertical antenna several miles high to tap the Earth's 100 volts-per-meter calm day E field. Then you hack up some sort of efficient DC-DC down-converter at the bottom.

Uh Huh. Sure.

5 Volts From One AA Cell

Fortunately, a lot more genuine progress has been made by going the other way, stepping up the voltage of one or two AA cells into the +5 volts needed by many hacker projects.

Maxim has a new MAX-655 chip and a handy 655-EV evaluation kit that goes for \$25. The kit includes the printed circuit board and all the parts you'll need to step a pair of AA cells up to a regulated +5 volts dc at currents of 170 mills or less.

Figure two shows you a type of switching mode power supply called a *step-up* converter. If you do not close the switch, the output voltage will equal the battery voltage, minus the diode drop. If you *briefly* close the switch, the current in the inductor will start increasing at a linear rate. When you open the switch, the higher current in the inductor will be forced into the load and stored by the output capacitance. By carefully changing your on-off duty cycle, you can provide any output voltage that is *higher* than the input battery voltage.

There is one problem with this classic circuit when it comes to low input voltages. Any MOSFET switch likes to have ten or more volts on its gate to give you an acceptably low turn-on resistance. To beat this, the MAX655 has *two* step-up converters in it. The first generates a low current and high voltage that gives the switch in the main converter a low enough turn-on resistance.

This is what a model hobbyist would call a *shake-the-box* kit. Just drop the parts in place, being careful to watch the polarity, solder it up, and away you go. Assembly time should be around nine minutes. I suggest adding your own 14 pin IC socket, rather than actually soldering the regulator in place. This is an ideal

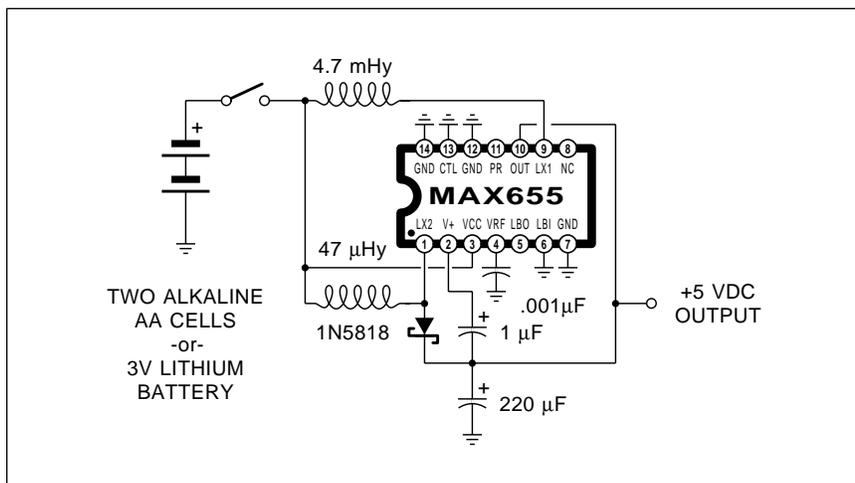


Fig. 3 – THIS MAXIM POWER SUPPLY KIT gives you a tightly regulated +5 volts DC at 170 mills or less from a pair of ordinary alkaline AA cells. The secret is a second internal switching regulator that gets used to raise the efficiency of the main one. Do not substitute any parts.

first hardware hacking project.

One warning: The two inductors and the Schottky diode are critical. If you do not chose *exactly* the parts supplied by *Maxim* or their *exact* recommended substitutes, your circuit can end up either inefficient or not work at all. Random junkbox inductors tend to have too high a DC resistance and may saturate.

Fortunately, all three of these are cheap parts. In quantity, the entire supply can cost well under \$6.

Maxim also offers a MAX654 that runs on a *single* AA cell and can start at an incredibly low 1.15 volts.

By the way, AA flashlight cells provide considerably more energy at lower costs in less volume than by using a 9 volt battery. Except when you need ultra low currents for a very long time. Which can give the 9 volt approach a slight edge. More on this in the free *Maxim Design News*.

Smoothing Fuzzy Data

Every once in a while, I like to take time out and play with pure math. I do this by just shoving some numbers into a computer or laser printer and seeing where it can lead. In the past, this has gotten me into such useful wonderments as the pseudorandom sequences, equally tempered music, *Fourier* synthesis, fractal ferns, stock market analysis, for quadrature art, nonlinear transforms, Bezier secrets, phase plane plots, wavelets, and, of course, the avuncular sleezoids.

I overwhelmingly prefer to use the *PostScript* language for this. Besides the absolutely unbeatable graphics, *PostScript* is a totally general purpose computer language that can do most anything that *Basic* or *C* can. And often do so in a simpler and far more obvious manner. Besides being lots of fun and easy to understand.

One fairley common hardware hacking problem is taking a bunch of sloppy data points and drawing a smooth curve through them. You might want to do this for a lab report, to produce an engineering data curve, or to try and convert some noisy bit-map, scanned, or hand coded input into smooth outline typography.

Some samples of smoothed data points are shown you in figure four, while the hairy-looking equations appear in figure five. You can get the

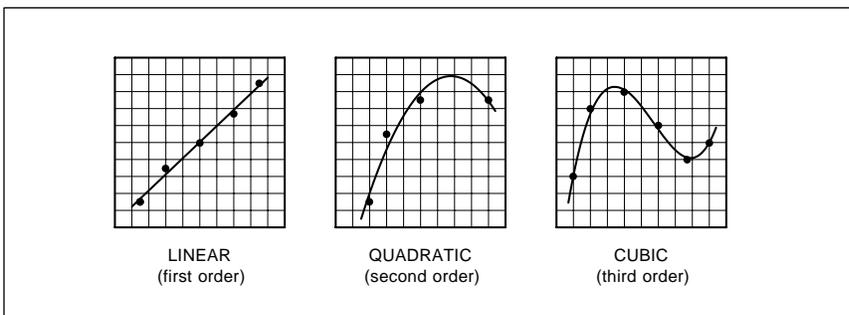


Fig. 4 – SMOOTH CURVES CAN be quickly and drawn through fuzzy or noisy engineering data by using the *PostScript* language and the least squares fitting method. Here are three popular types of curves which can give good fits to many hardware hacking problems.

documented *PostScript* code all ready to run as my file #294 FUZZYFIT.PS on *Genie* PSRT. Typical downloading costs should be twenty cents.

The best curve for any noisy data

usually uses what is known as a *least squares* fit. All this means is that you try to spread the errors out as evenly as you can. Your main reason for squaring is to make all the errors

(A) The **LINEAR** or **FIRST ORDER** least squares fit uses an equation of...

$$y = a_1x + a_0$$

Here are the two linear equations in two unknowns that you need to solve to get the best fit for your data...

$$(\text{sum}x^1)a_1 + (\#\text{pts})a_0 = (\text{sum}y)$$

$$(\text{sum}x^2)a_1 + (\text{sum}x^1)a_0 = (\text{sum}x^1y)$$

(B) The **QUADRATIC** or **SECOND ORDER** fit uses an equation of...

$$y = a_2x^2 + a_1x + a_0$$

Here are the three linear equations in three unknowns that you need to solve to get the best fit for your data...

$$(\text{sum}x^2)a_2 + (\text{sum}x^1)a_1 + (\#\text{pts})a_0 = (\text{sum}y)$$

$$(\text{sum}x^3)a_2 + (\text{sum}x^2)a_1 + (\text{sum}x^1)a_0 = (\text{sum}x^1y)$$

$$(\text{sum}x^4)a_2 + (\text{sum}x^3)a_1 + (\text{sum}x^2)a_0 = (\text{sum}x^2y)$$

(C) The **CUBIC** or **THIRD ORDER** least squares fit uses an equation of...

$$y = a_3x^3 + a_2x^2 + a_1x + a_0$$

Here are the four linear equations in four unknowns that you need to solve to get the best fit for your data...

$$(\text{sum}x^3)a_3 + (\text{sum}x^2)a_2 + (\text{sum}x^1)a_1 + (\#\text{pts})a_0 = (\text{sum}y)$$

$$(\text{sum}x^4)a_3 + (\text{sum}x^3)a_2 + (\text{sum}x^2)a_1 + (\text{sum}x^1)a_0 = (\text{sum}x^1y)$$

$$(\text{sum}x^5)a_3 + (\text{sum}x^4)a_2 + (\text{sum}x^3)a_1 + (\text{sum}x^2)a_0 = (\text{sum}x^2y)$$

$$(\text{sum}x^6)a_3 + (\text{sum}x^5)a_2 + (\text{sum}x^4)a_1 + (\text{sum}x^3)a_0 = (\text{sum}x^3y)$$

(D) For **QUARTIC** or **HIGHER ORDER** least square polynomial fits, just extend the math in the obvious direction for *n* linear equations in *n* unknowns. Solve for the coefficients. Little is usually gained by going beyond a third order polynomial. Especially in two dimensions.

(E) For least square fits to **OTHER EQUATIONS**, write out the least squares error equation. Then take partial derivatives with respect to each coefficient and set them to zero. This again leads to *n* linear equations in *n* unknowns.

Fig. 5 – HERE IS THE "MAGIC" MATH behind least squares curve fitting. My FUZZYFIT.PS *PostScript* program on *Genie* PSRT does it all for you quickly and painlessly. Just shove in the raw fuzzy data and out pops a smooth curve.

TESLA COIL & HIGH ENERGY RESOURCES**American Sci & Surp**

601 Linden Place
Evanston, IL 60202
(708) 475-8440

Edmund Scientific

101 East Gloucester Pike
Barrington, NJ 08007
(609) 573-6250

Industrial Micro

Box 596
Logan, UT 84321
(800) 359-0466

Lindsay Publications

PO Box 12
Bradley, IL 60915
(815) 935-5353

Resonance Research

E11870 Shadylane Road
Baraboo, WI 53913
(608) 356-3647

Science Probe

500-B Bi-County Blvd
Farmingdale, NY 11735
(516) 293-0467

Surplus Traders

Winters Lane, Box 276
Alburg, VT 05440
(514) 739-9328

TecSpec

3 Mine Mountain Road
Cornwall Bridge, CT 06754
(203) 672-0123

Tesla Book Co

Box 121873
Chula Vista, CA 91912
(805) 646-3371

Tesla Coil Builder's Assoc

3 Amy Lane
Queensbury, NY 12804
(518) 792-1003

positive, even if the data point lies *below* the curve you are fitting.

You have lots of choices of what type of curve to fit to your data.

One class of curves that make good fits to typical engineering graphs and most typography are usually called *polynomials*. These sometimes will also go by the name of a *Power Series Approximation*.

Here is a typical polynomial...

$$y = a_0 + a_1x + a_2x^2 + a_3x^3 + \dots$$

You pick as many terms for your polynomial as you think you need. For instance, a single a_0 term would give you a horizontal line with half the points above and half below. Dual $a_0 + a_1x$ terms give you a slanted line, again splitting the points.

Three terms gives you a *quadratic* or *parabolic* approximation. And four terms for a cubic. While you can go beyond a cubic, you'll usually gain surprisingly little extra in doing so.

One way to derive a least squares algorithm is to write out an equation for the total error for a given number of terms. Then you try to minimize this error by finding out how to separately minimize the error created by each individual term.

To find a minimum in an equation or on a curve, you find the *slope* of your curve and set it to zero. Math freaks will immediately recognize this minimization process as taking

the *partial derivatives* with respect to each coefficient and setting them to zero. Which results in a humongous mess known as *n linear equations in n unknowns*. You then solve the mess as best you can. Out pops your coefficients needed to plot your best fitting curve.

I personally use an old method involving *determinants*. The needed tools appear in FUZZYFIT.PS, while the tools and a detailed background tutorial is separately available as *GENie* PSRT file #289 LINEAREQ.PS. Incredibly, *only one single pass is needed to find the best possible curve, no matter how many terms in your polynomial or the number of points involved!*

Figure five does show you the equations to use for a linear slope, a quadratic, and a cubic fit. These are the ones you would be most likely to use. I'm sure I've just horrified all the genuine math freaks in our audience with my really weird notation here. But all (sumx³) means is to take your first x data value and cube it. Then take the second data value and cube it and add it to the first one, and so on for all the data. By (sumx³), I simply mean the sum of the cubes of each individual noisy x data value.

#pts is simply equal to your total number of noisy x,y data point *pairs* that you are trying to put your smooth curve through.

The (sumxy) expression means to multiply the first x value by the first y value. They you multiply the second x value by your second y value and sum them. And so on.

Fortunately, PostScript does all of your grunge work for you. Quickly, invisibly, and automatically. Around half a second to do the whole job.

Say you have five noisy data points and want to place the smoothest and most accurate possible cubic curve through them. All you do is...

```
[2 4 4 11 6 14 12 16 16 12]  
findcubicfit
```

And that's all there is to it! In this specific instance, your first data point is at $x = 2$ and $y = 4$. Your second data point is at $x = 4$ and $y = 11$, and so on. The *findcubicfit* operator then will automatically generate your needed magic a_0 , a_1 , a_2 , and a_3 best fit coefficients for you.

Among the other handy PostScript routines in my new FUZZYFIT.PS are *plotxyvalues*, which automatically draws the actual data points on the graph, and *ploteqn*, which sketches the smoothest possible curve through your points.

There's no sane limit to the number of data points allowed. Much of your typical engineering data gives a good fit to a cubic polynomial. Especially stuff that is only slightly nonlinear. Note that, roughly speaking, your a_0 coefficient is strongest at your *low* valued end of all the data. Your a_1 coefficient sets the initial *slope* of your data. Your a_2 coefficient works best in the *middle*, while your a_3 coefficient has by far the strongest influence at the *high* value end.

You can easily go beyond a simple cubic fit. If you know the underlying physical laws to your lab data, you can try and make your least squares fit the expected math. Other fuzzyfit curves of engineering interest include exponentials, sinewaves, statistical distributions, hyperbolas, circles, and ellipses. Your same "set the partial slopes of the error equation to zero" idea works well with these.

For graphics and typography, you can step up to a fancier method of curve fitting that permits loops and cusps. This goes by the name of *cubic splines*, or *Bezier Curves*. PSRT has lots more on this exciting topic.♦

Don Lancaster's

Hardware Hacker

November, 1991

SMPTE video time codes
Electronic dog tag contest
Case & enclosure resources
Solar energy breakthrough?
Photovoltaic panel bargains

We'll start off with our usual reminder that this is your column and you can get tech help and off-the-wall networking per the box below. Your best calling times are often weekdays 8-5, mountain standard time.

We have some really heavy stuff for this month, so let's have at it...

A Solar Energy Breakthrough?

Well, just maybe. It is far too soon to tell. But I guess we are overdue for a general update on solar energy.

On a bright Arizona day, you can figure around 1000 watts per square meter of incoming solar energy. This is a fairly diffuse and a rather weak energy source. A source that is made much worse by being there only some of the time. And made even more so by today's appallingly poor electrical conversion efficiencies.

Silicon solar cells are *inherently* inefficient when fed sunlight, which makes a diffuse energy source even harder to use. A semiconductor solar cell operates by receiving a precise packet of energy and then using that packet to release one electron to an external electrical circuit.

The energy of incident light is proportional to its frequency. $E = hv$ and all of that. At *one* single near-infrared frequency, the light energy packets are exactly the correct size needed by a silicon solar cell to get efficiently converted into electrical energy. All lower frequencies become largely useless waste heat.

What about higher frequencies? Only the magic energy packet size counts, so the higher frequencies will both generate useful power *and* extra waste heat. The higher the frequency, the higher your waste. The "spare change" above your critical energy level will get lost and appears to be unrecoverable. Sort of like a dollar tollbooth that requires you to dump *all* the change in your pocket.

When you consider the *entire* solar spectrum, the best possible overall efficiency you can get from a silicon solar cell is around 25 percent. This

appears to be a fundamental and unavoidable physical limit.

Out in the real world, silicon solar panels are much less than ideal, and you are very lucky to get an overall long term system efficiency above ten percent. And often less.

Which is dangerously close to the seven percent "breakeven" level, below which any solar panel will *never* pay for itself, owing to the materials and labor that go into the system, and the time value of the money used to finance the construction.

At seven percent efficiency, a one meter square solar panel will generate around half a kilowatt hour per day, or around \$5 of electricity per year.

Yes, there are tricks you can pull to raise your efficiency. Such as using a pair of different semiconductors having different work functions. Or using concentrators. Or heating water

with the waste heat. Or trying to re-shuffle or "downconvert" your solar spectrum to the magic frequency. But these seem mostly laboratory pipe dreams that, in my opinion, are unlikely to see the light of day.

In fact, the existing solar electric power plants are actually being torn down, owing to low efficiencies and really bad economics. Many hackers should be interested in the great bargains in the used (and somewhat degraded) solar panels now being offered wholesale by *Carrizo Solar* and retail by *Surplus Traders*.

Instead, "what if" our sun was a radio source? You would simply get an antenna and a rectifier, and high direct solar-to-electric conversion efficiencies can now be yours. This is called a *crystal set*, and all of the technology does appear to be fairly well proven. Efficiencies near 100

(A) LATERAL TIME CODE...

This older and nearly obsolete code needs an auxiliary audio channel and outputs one 1200 baud code string per video frame. The tape **MUST** be in motion for reading. The code is synchronized to begin on the fifth horizontal scan line of the first field in the frame. The low state equals 0 IRE units and the high state equals 80 IRE units.

The data stream is 80 bits long and follows the format of figure 2. It uses Manchester, or biphasic encoding that is self-clocking and can be read in either direction. Various bits in the data are assembled into BCD words identifying the frame, the seconds, the minutes, and the hours. Other bits are used for synchronization, time adjustment, simple parity and special use flags.

Reference: SMPTE 12M-1986

(B) VERTICAL INTERVAL TIME CODE...

This newer and widely used code is embedded each field on single horizontal lines during retrace. The code gets repeated two, and sometimes four times, beginning on line 10 of each field's vertical retrace interval for improved noise immunity. The code begins 10.5 microseconds into the line.

The tape can be stationary or moving in either direction. There are 90 bits to the code, sent at a stationary rate of approximately 1.8 MHz. The format appears in figure 3. It also uses Manchester, or biphasic encoding that is self-clocking and can be read in either direction. Various bits in the data are assembled into BCD words for the field, the seconds, the minutes, and the hours. Other bits are used for sync, time adjustment, full CRC error checking, and special flags.

Reference: SMPTE RP-108

Fig. 1 – THE SOCIETY FOR MOTION PICTURE ENGINEERS, or SMPTE offers these two standard time codes for video production or editing.

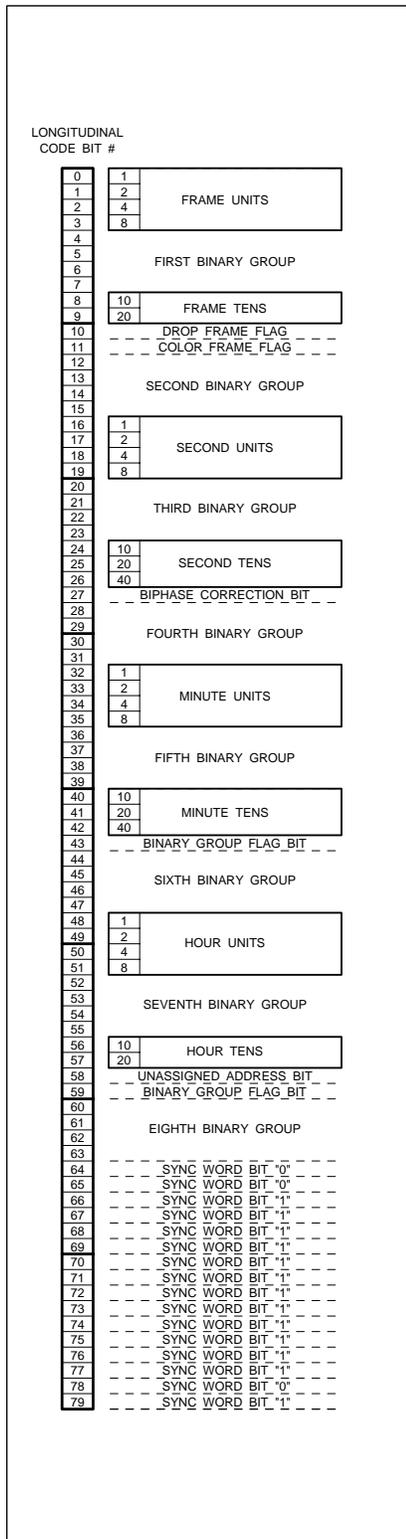


Fig. 2 – THE SMPTE lateral time code needs both a separate audio channel and a full frame to output at its 1200 baud rate. The tape must be in motion for reading.

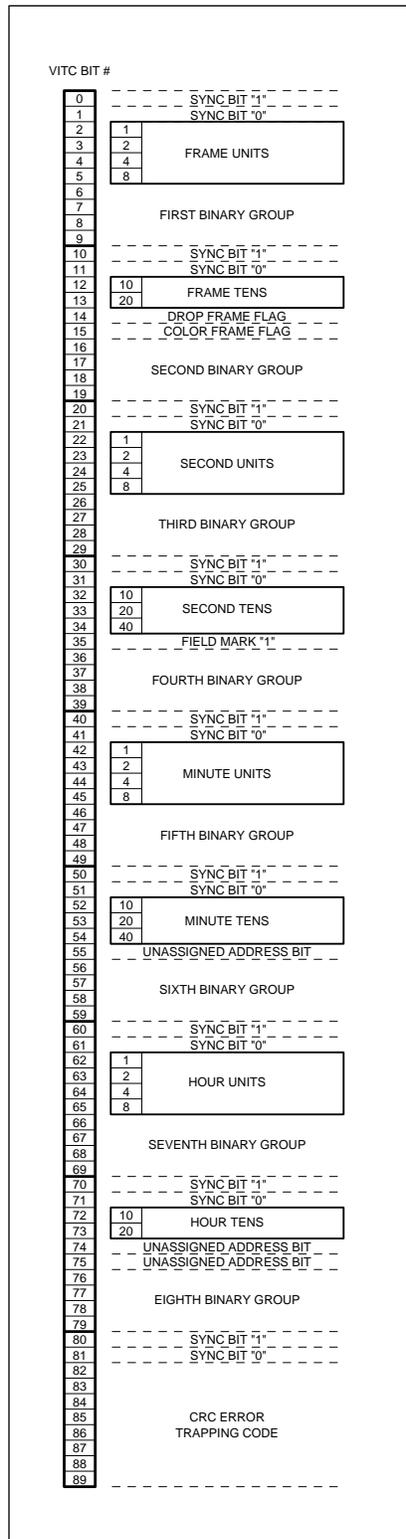


Fig. 3 – THE SMPTE vertical interval time code is sent each field on a blank horizontal line at a baud rate of 180 Kilohertz. The tape could be stationary or move either way.

percent would be theoretically possible. With any care at all, the real world long term efficiencies would not have to be that much worse. Your same square meter panel could approach \$80 per year in electricity, a much more attractive value.

The only little problem is that, until now, nobody was quite sure what an optical antenna or an optical rectifier was. Enter an individual researcher by the name of Alvin Marks who uses crossed pairs of a special *Lumeloid* film that uses the antenna/rectifier method for a direct solar conversion. Figures now including an 80 percent efficiency and a penny per kilowatt hour are being bandied about.

This does look legit. No obvious physical laws are being broken and the *Electric Power Research Institute* has seen fit to throw some cash at the idea. And we are certainly getting much better at working with stuff the size of optical wavelengths.

All of this is brand new and was rushed to meet this month's *Hardware Hacker* deadline. All the info I have on it so far is the brief note in *Business Week*, August 12, page 49.

For more on direct solar conversion, stay tuned or check into my PSRT bulletin board on *GENIE*. Other obvious news sources include *Science News*, *Science*, and the technology section of the *Wall Street Journal*.

For ongoing technical info, do try *EPRI* or else the *Dialog Information Service*. The search keywords could include *solar*, *Marks*, *Lumeloid*, *power*, *EPRI*, and *energy*.

Finally, for the ongoing grass roots shirtsleeves solar energy info, be sure to check out that really great *Home Power* magazine and the new *Photovoltaic Network News*.

Video Time Codes

We are shortly going to see lots of new software and hardware that will make any totally professional video production on a mainstream home computer system roughly as complicated as writing a business memo with a word processor. And that's *real* editing on a precise field-by-field basis. With the full genlock, overlay, station sync, anti-aliasing, and color keying. Plus all of the "gee whiz" bells and whistles.

Real editing demands that you can

locate and identify each and every individual field in the entire video. This normally gets done by using a *video time code*.

Figure 1 summarizes the two most popular time code systems in use today. Both of these are standards published by the *Society for Motion Picture and Television Engineers*. A useful *Time Code Handbook* is now available through *Cipher Digital*. It includes these SMPTE code standards along with the related MIDI electronic music timing code.

My copy was free, but they may panic when they see the humongous stack of reader service responses they are certain to get from this column.

The human persistence of vision is somewhere around 40 to 50 Hertz, so tricks have to be played to minimize the flicker of many motion displays. For instance, with any 35 millimeter movie, the light is turned off and a frame is suddenly moved into position by using an intermittent action known as a *Geneva Stop Mechanism*. The light is turned back on by a beam interrupter. The light is turned back off. The light gets turned on again, *projecting the exact same image a second time*. Finally, the light gets turned off and your next frame is moved into position.

We say the sound movie uses a *frame rate* of 24 frames per second. The *field rate* is 48 fields per second. In this case, the two fields per frame are identical.

With standard television, you have a frame rate around 30 frames per second. Each frame gets broken into two fields, one containing the odd scan lines, and another containing the even scan lines. This is known as *interlace* and gets used to reduce the display flicker. The field rate is near 60 fields per second.

Color tv introduces a further complication in that successive frames must be paired as *Frame A* and *Frame B*. This is done to reduce color sub-carrier visual artifacts. Thus, only the multiples of *two* frames or *four* fields should ever be cut or edited. A glitch results if B does not always follow A, and vice versa.

The original or *Lateral Time Code* standard was first intended for movie film, and later adapted to videotape. This largely obsolete code gets sum-

marized in figure 1 and is detailed in figure 2. The lateral time code needs a separate audio channel. An entire frame is used to transmit 80 bits of digital data at a normal rate of 1200 bits per second. *The tape must be moving*, either frontwards or backwards before this time code can be read. There is also no provision for error trapping.

A *Manchester* or *biphase* coding is used. This just means that each bit changes at its beginning. A one bit also changes at its middle; a zero bit does not. A code of this type is inherently self-clocking and can be read in either direction. The first data bit is supposed to start off on the fifth tv horizontal line

Those individual bits are largely grouped by fours into *Binary Coded Decimal* words. These become the units and tens of the frames, seconds, minutes, and hours. There are also some special bits used for sync, user definition, and specific flags. This lateral code is slow enough that it is easily read with machine language code by just about any computer or microcontroller.

Their newer, or *Vertical Interval Time Code* is related but is far more sophisticated. It is summarized in figure 1 and detailed in figure 3. The entire 90 bit time code is transmitted within a single horizontal line. The chosen line should fit somewhere between blanked retrace horizontal lines 10 and 20.

The code must be transmitted twice per field on non-adjacent horizontal lines, and often is transmitted four

times for extra noise immunity.

A similar Manchester or bi-phase encoding gets used. This one has a much higher bit rate, typically around 1.8 Megahertz during a pause. The time code burst begins 10.5 seconds into the selected horizontal line.

The VITC can get read while the tape is stationary or moving in either direction at any reasonable speed. Error trapping and other special bits are also included in the code.

Unfortunately, the bits do fly by a tad too fast to catch using machine language code on most mainstream microcomputers. So a special fast decoder is needed. Faster yet if you want to search and anticipate during a fast forward or rewind mode. But the logic is simple enough for most PLA or EPLD devices. A dual port RAM or an intelligent peripheral driver could make a useful computer interface.

I do not yet know of a custom time code single chip, but it is reasonable to expect a cheap one shortly. And several simpler but nonstandard field codes are being introduced in new video products, especially by *NEC*. There have also been lots of helpline requests for a simple and automatic time code inserter for home video editing use. Let me know what you'd like to see on this.

Fancy Case Resources

What can you do when you need an outdoor rated and waterproof case for all your electronic projects? For this month's sidebar, I've tried to round up some of the more obvious sources for premium enclosures.

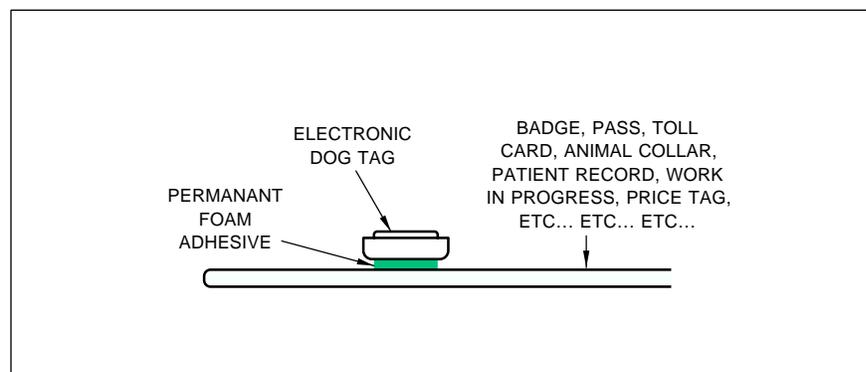


Fig. 4 – ELECTRONIC DOG TAGS using the cheap and durable Maxim DS1990 series of touch memory chips can get stuck on virtually anything. They do offer electronic readable serial numbers and several thousand of bits of read-write non-volatile memory. These are the shape of a coin cell and last for ten years.

Unfortunately, many of these are staggeringly expensive and hard to get. But, by playing in the cracks, you may be able to come up with a useful workaround.

JerryCo, who've recently renamed themselves as *American Science and Surplus* sometimes have great cases at unbeatable prices. Their #10827 and #21085 both cost around \$4.

The most obvious source for the "suitcase" style packaging is *Jensen Tools*, who do stock everything from leather through plastic to aluminum to stainless steel. And the ultimate in military quality primo cases come from *Zero Manufacturing*. At the ultimate in military primo prices.

But the fancy electronic case I am the most impressed with is not an electronic case at all. This is the *Guard Box* that is offered by *Pelican Manufacturing*. A reinforced structural resin case measuring roughly 3 x 6 x 8, it comes in four bright colors, and costs around \$7 in your smaller

production quantities.

This box is airtight and watertight to thirty feet of depth. A handle, a hinged O-ring sealed cover, and positive closure snaps are included. It is ideal for, perhaps, a solar panel controller. Larger sizes and custom colors are also available.

Several other manufacturers of quality (e.g. expensive) electronic cases are also included in our listing. Please do let me know if I missed anything obvious or if you have any favorites of your own.

Electronic Dog Tags

We've seen a number of times in the past how *Dallas Semiconductor* has come up with really great and super hackable integrated circuits. This time they have totally outdone themselves.

They call their new product line *Touch Memory*, or *Self-Stick Chips*. A typical unit is shown you in figure 3. What you have here is a low cost and

durable stick-on data acquisition and storage system the size and shape of a coin cell battery. You glomp this onto *anything*, such as a badge, a ticket, an animal collar, a security access card, a medical patient, or a product being manufactured or shipped.

Inside is a 10 year lithium cell and some unique electronics. Depending on the version, the fancy electronics gives you either a plain old 48 bit serial number or else thousands of bits of read-write memory.

Obvious advantages over a printed bar code label are that (A) much more info can be stored, (B) you can update it at any time, (C) no expensive laser reader systems are needed, and (D) the stainless case is far more durable and rugged than a paper label.

What is really unique is that there is only a *single* contact plus the case ground. Which is all you need for reading and writing. Figure 5 shows you how one lead can be used to both read and write. Your host computer or whatever will first input your serial activation data string. Your touch memory will then respond, returning a serial number and/or your data.

The single contact is exceptionally easy to access. There's none of the alignment or fragility problems that you might have with more traditional connectors.

Several different styles are newly available. The cheapest outputs only a 48 bit serial number. Fancier versions can read or write to 1K or 4K bits of internal non-volatile ROM. On yet others, a security code prevents just anyone from reading or altering the contents. This gets important on such things as a bus fare pass.

The reading and rewriting process is destructive, so very bad things can happen with an erratic contact or a partial write. To beat this, your info is first written to an internal scratchpad area. Only the complete and correct write later gets transferred to main memory. An internal checksum is also provided to let you know if your data is still valid.

Free samples and more technical details are available directly from *Dallas Semiconductor*. Cost is in the \$1 to \$3 range, depending upon the chip features and complexity.

For our contest this month, just tell me something off-the-wall you would

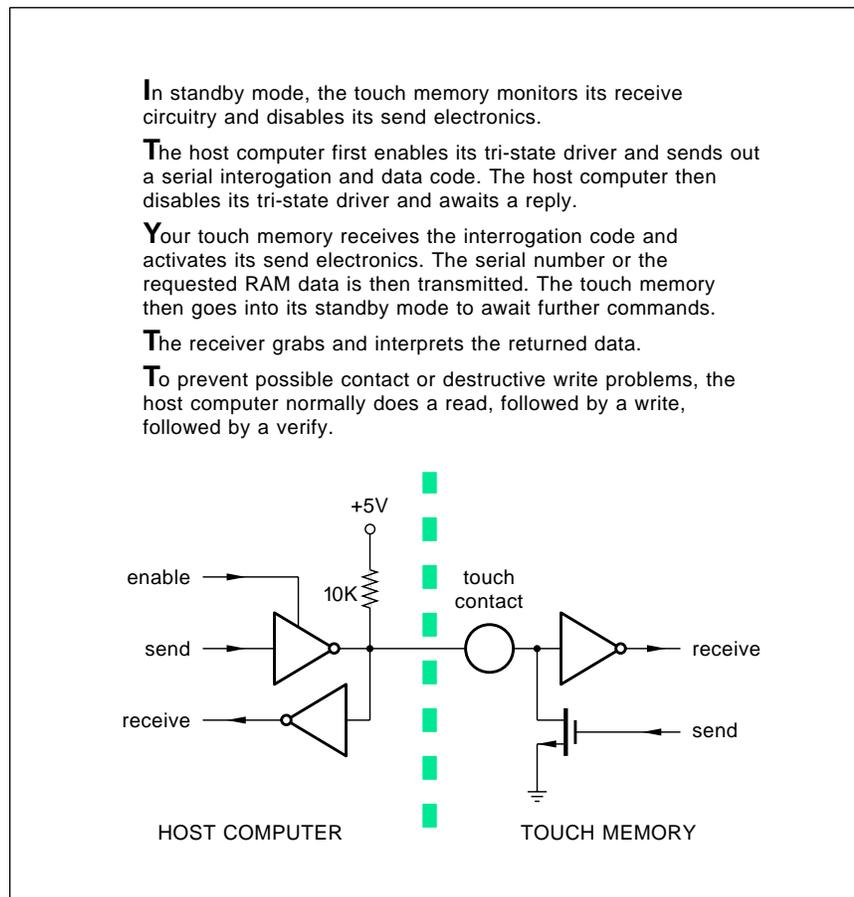


Fig. 5 – ONLY A SINGLE CONTACT IS NEEDED to read from or write to your touch memory. Here is how it gets done.

do with an electronic dog tag. There should be all of the usual *Incredible Secret Money Machine* book prizes, with a great all expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.

As usual, send your written entries to me here at *Synergetics*, and not to **Radio-Electronics** editorial.

Power Electronics Update

Here are several new updates to our previous columns: One historic key "horses mouth" paper for doing your own induction motor speed controls is *Pulse Width Modulated Inverters for AC Motor Drives*, B. Mokrytzki. IEEE Transactions IGA-3, number 6. Nov-Dec 67, pages 493-503.

Another pair of power electronics resources are the new *Motortronics* and *Powertronics* trade journals.

New Tech Lit

From *PMI*, a new *Audio Handbook*, volume one that covers the older SSM analog electronic musician products. Included are nineteen excellent ap notes on synthesizer concepts. From *Cypress Semiconductor*, a new *MOS Databook* on their unique memory and programmable logic products. And from *Signetics/Phillips*, a new *Master Product Catalog* on all of their analog and digital integrated circuits. Included are such oddball goodies as cellular radio chip sets.

Motorola has their new *Pressure Sensors* booklet available, along with a lit packet on their transducers. By far your very best sources for ultra low cost pressure sensors still remain *SenSym*, *IC Sensors* and *Novasensor*.

Zilog has their new *Shortform 91* catalog on microcontrollers, microperipherals, and telecomm stuff. A new *Technical Guide and Cross Reference* on replacement semis is now available from *NTE* at \$3.25.

Printed Circuit Design is a new trade journal that is heavy on new pc layout tools and software. And an interesting *Gas Density Calculator* slide rule is available from the folks at *Fisher-Klosterman*.

From *SGS* a new *Power Modules Databook* on high power transistors, Darlingtons, diodes, and MOSFET arrays. And from *Siemens*, the *Optoelectronics Data Book* on all the usual LED lamps, arrays, sensors, couplers,

and photodiodes. From *Waferscale Integration* a new data book on *High Performance CMOS Memory*.

A really exciting new integrated circuit that I've yet to do anything with is the *Philips SAA7199* digital encoder. It accepts RGB computer inputs and outputs full NTSC (Never The Same Color) or PAL (Phase Alternating Line) top broadcast quality video. Included is a full genlocking capability and a powerful computer interface. Wow.

You might find the free *Personal Engineering* trade journal of interest. It mostly covers high end CAD/CAM software and circuit layout programs. My own preference, of course, is to do the same thing with *PostScript* and a favorite editor or word processor. Far cheaper and far more flexibly. But that's me.

The *American Voice I/O Society*, and otherwise known as AVIOS does exactly what you'd expect them to. They also promote some conferences and seminars on speech synthesis and recognition.

A freebie folder full of electronic tubing samples is available through *Markel* who stocks everything from shrink tubing up to a very high temperature sleeving. One collection of books on energy management, air conditioning, and humidity control, is available through the *Business News Publishing Company*.

FANCY CASE & ENCLOSURE RESOURCES

American Sci & Surp

601 Linden Place
Evanston, IL 60202
(708) 475-8440

Bud Industries, Inc

4605 East 355th Street
Willoughby, OH 44094
(216) 946-3200

Carlton

25701 Science Park Drive
Cleveland, OH 44122
(800) 321-1970

EAI

37 Sherwood Terrace S124
Lake Bluff, IL 60044
(708) 295-6664

Hoffman Engineering

900 Ehlen Drive
Anoka, MN 55303
(612) 422-2177

Jensen Tools

7815 South 46th Street
Phoenix, AZ 85044
(602) 968-6231

Lansing Instrument

PO Box 730
Ithaca, NY 14851
(800) 847-3535

Pelican Products

2255 Jefferson Street
Torrance, CA 90501
(213) 328-9910

Rose Enclosures

7330 Executive Way
Frederick, MD 21701
(301) 696-9800

Zero Corporation

777 Front Street
Burbank, CA 91503
(818) 846-4191

Let's see. I've just reprinted my *Incredible Secret Money Machine II*, along with a new intro and update section. And for more on PostScript, I stock the best books and software by the best authors in my bargain-priced *The Whole Works* package.

This is the fastest and best way to get up to speed on using and profiting from PostScript.

The usual reminder about my new BBS up as *GENIE PSRT*. Besides all of the PostScript and desktop publishing stuff, you'll find all sorts of ongoing *Hardware Hacker* and our *Midnight Engineering* resources here. For the fundamentals of digital integrated circuits, do check into my classic *TTL Cookbook* and *CMOS Cookbook*. Lots of autographed copies are available from my own *Synergetics*. My newest and best *Book-on-demand Resource File* should also be ready by the time you read this. Give me a call per the helpline for more info. Or email me on *GENIE PSRT*.

Finally, I do have a pair of new and free mailers waiting for you. One includes dozens of insider hardware hacking secret resources, while the second covers PostScript and Desktop Publishing. Write or call for info.

Our usual reminder here that most of the products and services mentioned appear either in the *Names and Numbers* appendix or above in the *Case Resources* sidebar. ♦

Let us start things off with a bunch of updates to some of our previous topics. Along with some new answers and random comments to a few of our more asked helpline calls...

FM Stereo Broadcasters— The Rohm BA1404 FM stereo transmitter chip really has been popular, and a dozen sources now exist for kits via ads in *Radio-Electronics*, in *Nuts & Volts*, and elsewhere. This stunning micropower and low cost chip was originally intended to ease adding a CD player to your car radio. You just unplug your regular antenna, insert a module containing the BA1404 into the radio, and your old antenna into the new module.

Presto. Instant and hassle-free high quality stereo access to your car audio system. The fact that the chip made a really great wireless broadcaster was an afterthought.

But there are problems with some of the kits. Some do not use a crystal for the 38 kHz stereo pilot subcarrier, that can lead to drift and adjustment hassles. A suitable 38.4 kHz crystal is cheaply available from *Statek*.

A second problem is that many premium FM receivers are synthesizer controlled these days, and *demand* a frequency that is *exactly* on channel. Older and cheaper FM receivers had an AFC analog frequency lock that could grab any old frequency and follow it as it drifted around.

Can you *directly* crystal control a broadcast quality FM transmitter? Not really. Because you are asking for a something that is both ultra "stable" and instantly able to accurately "drift" over a wide frequency range as it is being modulated.

Instead, you normally would use an *indirect* method to stabilize your FM transmitter. You should add a small varactor diode (say 10 pf) across your tank so that you can tune your tank circuit by using a DC control voltage. Details on this in Rohm's ap-notes. Then, you divide down your output frequency to average out your modulation and compare this against some

reference. A DC control voltage is then derived to hold you onto your frequency. Phase lock loop style.

I'm checking out several suitable circuits, so stay tuned. Or else send me your favorite solution to this on-going circuit hassle. What's really needed here is a low cost, low power single chip synthesizer.

Alternators as Power Steppers— Yes, they definitely do work, and an amazing number of hackers have already picked up on this on their own. The important uses now include

animation stands and computer controlled wood routers. One videotape I received was quite impressive.

This is an interesting example of *synchronicity*. If the time is right for something, it should emerge from dozens or hundreds of apparently independent sources. By the same token, attempting to patent your "new idea" is almost certainly futile, again because of synchronicity.

Word has it that rewinding your alternator gives you by far the best results. Try something around twenty

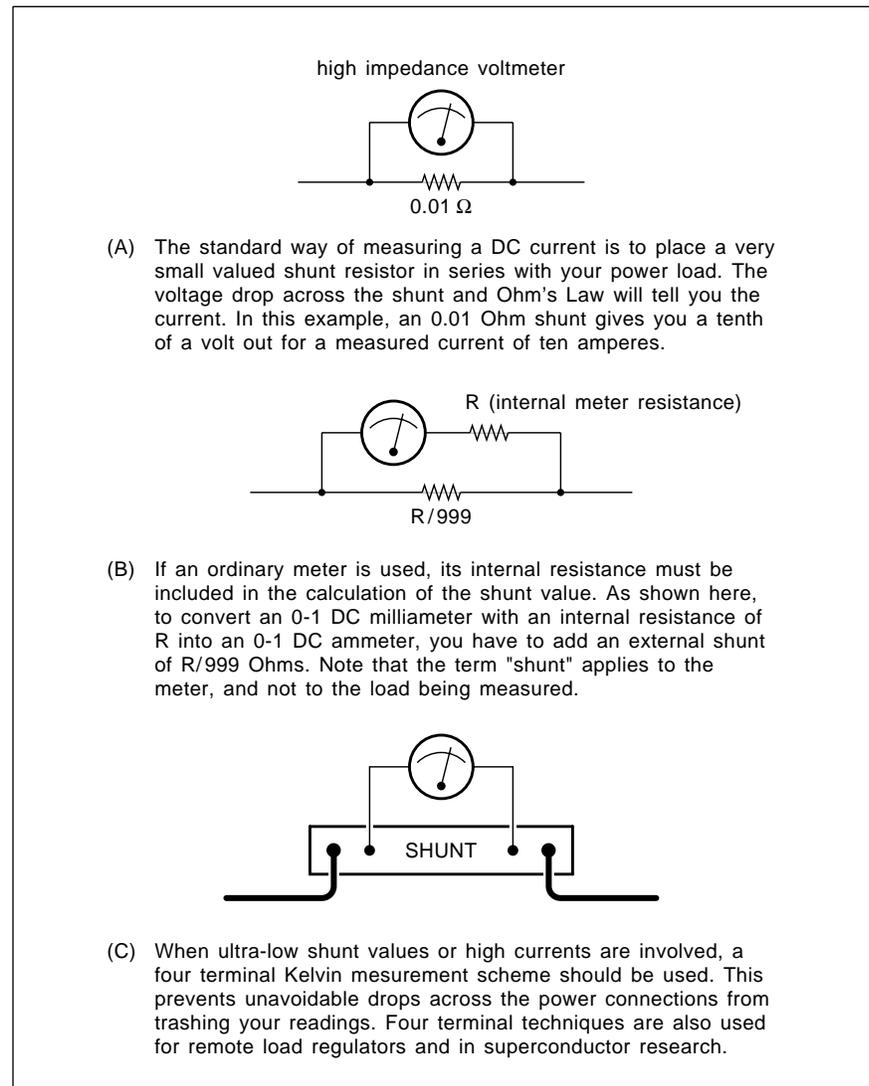


Fig. 1 – SOME OF THE FUNDAMENTALS of DC current measurement.

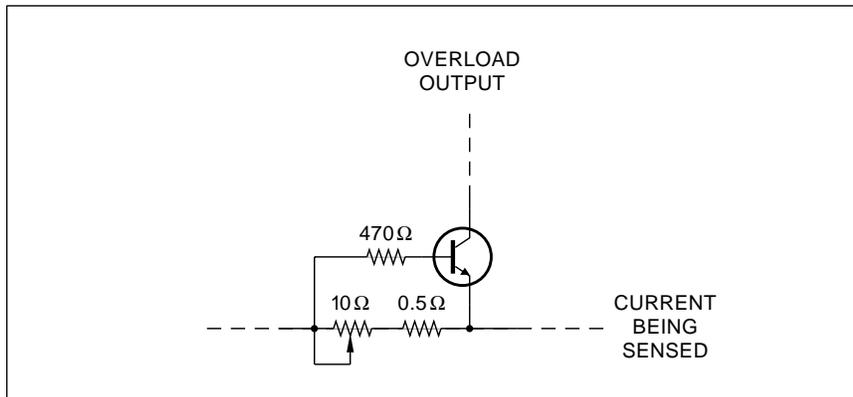


Fig. 2 – THIS SIMPLE CURRENT LIMITER is adjustable over a 50 ma to 1 ampere range. Use the collector current to pull down a reference or otherwise reduce your input current or source voltage.

feet of #26 wire *per pole* and straddle only one single pole (instead of the usual three) with each winding.

The driver circuits that I showed you purposely held back on the power to keep you from burning things up on your first cut. Naturally, you'll go to higher power and properly current limited two-level drivers as you improve your designs.

Video Time Codes– I forgot to tell you that the SMPTE vertical interval time code is usually sent on lines 13 and 15 of your field retrace. In retrospect, this code is horribly klutzy and incredibly inefficient. Owing mostly to its having to evolve from an earlier movie film standard and from primitive extraction electronics.

A bunch of newer time codes are

now emerging. All incompatible, of course. Both *NEC* and *Sony* are now pushing their own time standards on new consumer video products. More on these when I get a chance.

Our second most popular helpline topic (second only to caller id) is on the new VCR time code. The one that lets you look up a magic number in a directory or a video guide and easily program your VCR for an unattended recording. It turns out that the two developers of this recording code are Daniel Quo and Henry Yen. More info on the use and distribution of the code is available through *Gem Star Development Corp.*

At present, their code is "secret". Naturally, that won't last for long, and you can expect either complete

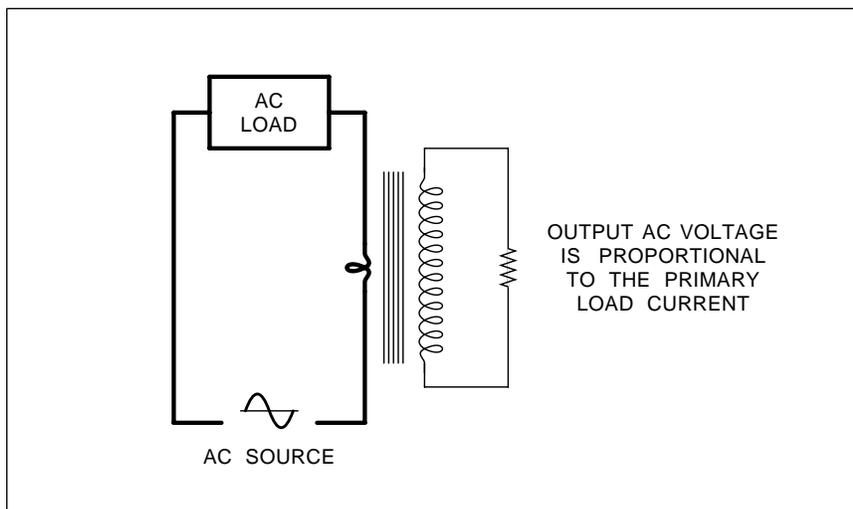


Fig. 3 – A CURRENT TRANSFORMER is just a transformer that has a very low impedance primary (often ONE turn or less) and a high step up ratio. The voltage across the secondary is proportional to the primary current.

technical details or else a fully open substitute to evolve shortly. Consult the usual suspects.

To me, it makes infinitely more sense to derive a simple code based on channel, time, date, and duration. One that anyone can apply and use. Most computer manufacturers have learned long ago that open is the *only* way to go.

Witness Adobe System's fortune skyrocketing when they released the *black book* showing how their super secret type I PostScript fonts were encrypted. In reality, all their highly touted encryptions were an outright joke. Why? Because any computer-literate seventh grader could trivally crack their code with a little patience and zero insider knowledge. But that's another story. See my *Ask the Guru II* reprints for details. And I do stock some black books here.

Fractals and Chaos– One of the shortcomings of James Gleick's popular *Chaos: The Making of a New Science* was that it was a tad shallow in spots. It would lead you up to lots of great stuff, and then leave you with nowhere to go. This has now been cured in spades through *Chaos: The Software* from Autodesk. This \$59.95 software package uses a color VGA on any IBM PC or clone. It includes stunning and spectacular interactive demos of Julia sets, Mandelbrot sets, chaotic pendulums, strange attractors, chaos games, fractal forgeries, toy universes, and bunches more.

One major emerging use for the fractals is in video compression. The *Iterated Systems* people have just introduced a unique series of new products. These include their *POEM Fractal Factory* and *POEM Fractal Slide Projector*. Amazingly, these use *software only* to decompress a full animation in real time. And at compression rates approaching 100:1. Sadly, the compression process is very slow and requires expensive and custom hardware and software. Their new compression scheme is ideal for such uses as CD ROM.

Much more info on all of these topics does appear in my *Hardware Hacker II & III* reprints.

Current and Current Sensing

Accurately sensing or measuring an electrical current can get tricky.

Especially when AC is involved or when breaking the primary circuit is a no-no. Let us do a quick review of several of the current sensing fundamentals and see just what hacking opportunities it leads us to.

In general, there are two main methods of sensing current. With the *direct* method, you will insert an appropriately low resistance or an impedance in series with your load and then measure the voltage drop across that impedance. With the *indirect* method, you try to accurately measure the strength of the magnetic field created by a conductor carrying your load current.

Figure one shows us three stock direct current ammeter schemes. In 1-A, a low value resistor known as a *shunt* is placed in series with your load. You then measure the voltage drop across it with a "perfect" high impedance voltmeter. For instance, an 0.01 ohm shunt will give you a tenth of a volt out for ten amps in.

Shunts can be anything from a piece of paper clip (thank's to Steve Ciarcia) to precision and temperature compensated devices. Sources of shunts include *Simpson*, *Triplett*, and various advertisers found in those *Measurement & Control* and *Sensors* trade journals.

It gets slightly trickier when you use a shunt to increase the range of an ordinary milliammeter, rather than a "perfect" high impedance voltmeter. Details per figure 1-B. Say you have an 0-1 DC milliammeter of internal resistance R . Your shunt to convert it into an 0-1 DC ammeter should have a value of exactly $R/999$. Such that the combined parallel resistance of your shunt and the meter resistance ends up precisely $R/1000$.

The amount of voltage drop across your shunt will depend on the input current, the shunting resistance and Ohm's law. The lower the R value of your meter, the less voltage drop you will get across your shunt when you measure high currents.

Since all high current shunts are extremely low impedances, you have to be very careful that voltage drops across your meter and all your load connections do not inadvertently get included in your measurement.

Which leads us to the *four terminal* or *Kelvin* connection shown in figure

1-C. You only measure the voltage drop across one precisely known *portion* of your shunt. This guarantees any external high current connections are *outside* of the voltage drop being accurately measured.

A variation on this four terminal technique can let you use a voltage regulator remote from its load. By feeding back your voltage sensing leads, you could include your main current drops *inside* your regulator and get more precision results. The trick, of course, is to make absolutely certain that none of the load current travels through the sensing leads.

A simple *current limiter* is shown in figure two. This one is adjustable over a 50 milliamperes to a 1 ampere range. It is based on a silicon NPN transistor requiring a 0.6 volt drop before it conducts. Whenever your transistor starts conducting, its collector current gets used to pull down a regulator or whatever, thus safely limiting your current.

As figure three shows us, current sensors for AC circuits often use a *current transformer*. This is a special transformer with a very low impedance primary and having a high step-up ratio. The ac voltage that is delivered to the load resistor is proportional to the current through the primary winding.

There are some very important

rules for current transformer use. The load must *never* be disconnected from a current transformer! Dangerous and possibly lethal voltages could result. Also obviously, you must not ever disconnect the primary in any live circuit.

Only the specified load resistor can be used or calibration will suffer.

Often, the primary can simply be a single wire through the core of your transformer. If you do use one single wire, some care is needed to get an accurate and repeatable reading. The wire should go straight through the exact center of your current transformer. It must not be allowed to move or vibrate.

On the other hand, sensitivity and accuracy can be improved by using several primary turns. But there may not be room in the core.

If the current transformer core can be opened in some manner, you can connect or disconnect your current transformer without physically disconnecting the current-carrying load wire. This gets very important when making any service and test measurements. Or when you want to avoid an electrician.

A *snap around ammeter* is one example of an openable core. When you glomp around your wire to be

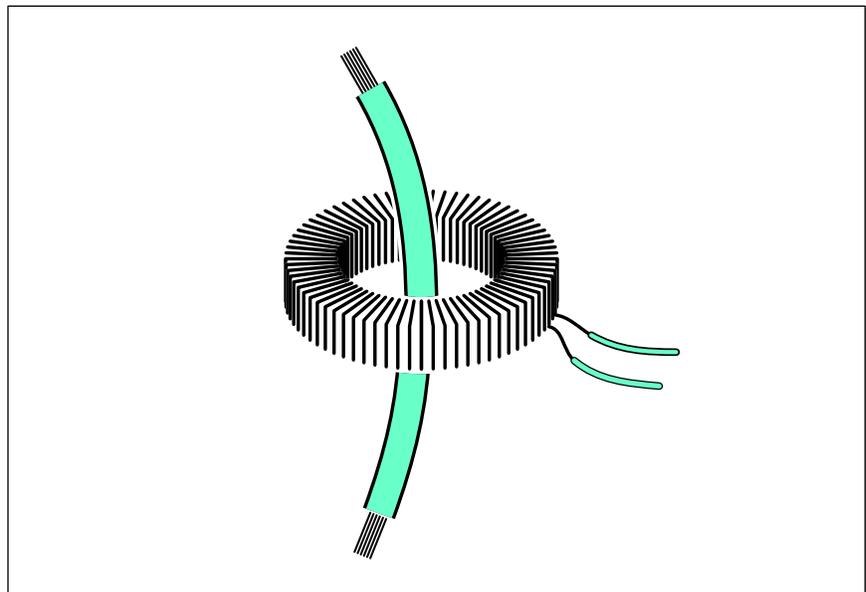


Fig. 4 – A TOROIDAL CURRENT TRANSFORMER is economical and accurate. It is also self-shielding. But you physically have to disconnect and thread the primary wire through the core center.

sensed, you are closing the core and completing a current transformer magnetic circuit.

Two important points. You must snap around a *single* wire. If you snap around a wire and its return path at the same time, the two currents will largely cancel out, leading to a useless measurement. And the magnetic path must be identical for each snap. Thus, your core must close together exactly and precisely. The same way each and every time.

I've found three good sources for low priced and eminently hackable current transformers. These include *Amecon*, *CR Magnetics* and *Toroid Corporation*.

The latter two offer toroidal current transformers, similar to figure four. These are priced in the ten to twenty dollar range. Some models include built-in LED safety monitors.

But by far the most hackable current transformer I have ever seen is the *Amecon* LD-50 load detector. This beauty costs under three dollars in quantity. Samples are available.

Now for the unusual part. Their LD-50 comes apart so you can install it snap-around style, without breaking your primary load wire. Wires of #8 size or smaller are acceptable.

Using a 50 ohm load, the LD-50 produces 50 millivolts per ampere and is useful over a 5 to 50 ampere range.

Which is ideal for most home power monitoring uses.

Speaking of which...

Home Energy Monitoring

Most people can save hundreds of dollars a year on their power bills, simply by finding out what electricity gets used when and by whom. And then attacking the worst of the power gobblers in a logical and a cost effective way. Step number one in this process is one or more current sensors connected to your home computer or microcontroller.

Probably the one single greatest obstacle to wide acceptance and use of home energy monitoring involves the hassles of current sensing. You do not want to rewire your house, hire an electrician or go to any expensive and fully approved devices. Instead, you would like to do something once by yourself that is simple and safe.

Figure five shows you one home energy monitor scheme that I call the *isopod*. A fully insulated and split tennis ball shaped pod gets snapped around one insulated line of a power cable. Inside is a current transformer and some black magic chips. Possibly from such outfits as *Dallas Semiconductor*, *Maxim*, *LSI*, or one of the other good guys.

The isopod derives all the power it needs from the sensed current. A

separate control receiver/transmitter is located a safe few feet away. This control box uses a lower frequency radio waveform to interrogate your isopod. If properly addressed, the isopod responds by returning a high frequency code burst equal to the current presently being measured.

Finally, the control box intercepts the data burst and converts the sensed current into standard serial data that a computer can understand.

As shown, the isopod would only measure and monitor current. This should be good enough for all typical home energy monitoring uses. But, by carefully synchronizing the start of your data burst to the a positive-going current zero crossing, your control box could measure its *own* voltage to determine the lag or lead and your actual real and reactive power.

Several channels could be made available by using different isopod addresses. This solves the dilemma of simultaneously monitoring both legs of the normal 220 volt, center ground home power system. Or of monitoring individual breaker lines.

Probably the simplest addressing scheme would be simple time delays in a *time division multiplex* setup. For instance a channel "3" isopod would wait 0.3 seconds (plus the next zero crossing) before any response. A channel "6" isopod would wait 0.6 seconds, and so on. This way, one single control box and one single interrogation command could read dozens of isopods.

You can probably get by snapping the pod directly onto your incoming power leads *ahead* of the meter. Up on the roof where they are easily open and accessible. The tiny extra power "stolen" from your utility would add half a cent to a \$200 monthly power bill. And the potential utility benefits in load shedding and load levelling would be much higher.

I can think of lots of other uses for a cheap and fully isolated, snap-on current sensor. Safely measuring high voltage industrial systems can be one obvious use. Getting info onto or off a rotating shaft or moving machine is a second. There's lots more.

And last summer I had a slightly but infuriatingly intermittent frost sensor in my heat pump. It sometimes insisted upon switching over to high

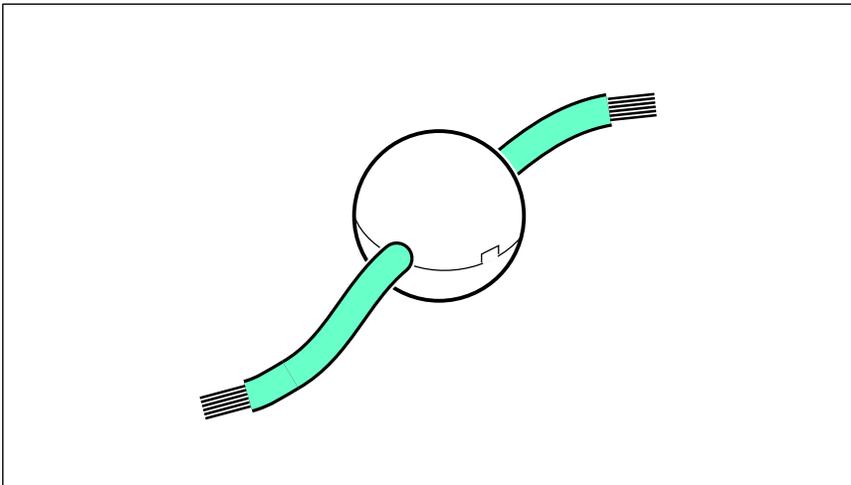


Fig. 5 – THIS "ISOPOD" CONCEPT can greatly simplify home energy management. The isopod glomps on one of your incoming power cables. Inside is a current transformer and some micropower electronics. On any addressable VLF radio inquiry from a nearby control module, the isopod returns your present current consumption as a UHF radio signal. Response is synchronized to current zero crossings so that both real and reactive power can be remotely measured.

emergency heat during the middle of an Arizona desert summer afternoon.

Those several wasted service calls and the perfectly good parts that were unnecessarily replaced could have been eliminated by several snap-on isopods that monitored and recorded what was going down.

But why don't you tell me instead? For this month's contest, just tell me what you would do with one or more isopods. Or else contribute somehow to our home energy dialog. There will be all of those usual newly revised *Incredible Secret Money Machine II* books going to the dozen best entries, with a great all expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the best of all.

Getting Standards Info

Where do you go to get a copy of EIA standard RS-232? Two obvious places to start include the *Encyclopedia of Associations* on the reference shelf of your local library. Or, for government standards, try the main *Federal Information Center* phone number of (800) 359-3997.

To make things easier for you, I've gathered up most of those standards associations and resources of hacker interest together for you into our resource sidebar for this month.

Two quick notes. *ANSI* is just the American arm of the international *ISO*. They are pretty much one in the same. And the *US National Bureau of Standards* has long ago changed their name over to the *National Institute of Science and Technology*, or *NIST*.

Actually, RS232 has been largely replaced by the MacDonald interface. Jerome R. MacDonald is the senior member of a design team in the dairy science division of the *US Department of Agriculture* who has come up with a fast, convenient, error-free, and fully networkable serial comm setup. Its use rapidly spread to other government agencies, to hackers, and finally to industry.

The great MacDonald interface is presently up for *Electronic Industries Evaluationary (EIE)* status. Thus, the old MacDonald farm interface is now an EIE I/O.

New Tech Lit

From *Hitachi*, an *Audio and Video IC Data Book* chock full of unusual

STANDARDS ASSOCIATIONS & RESOURCES

Am. National Stds. Ins. 11 West 42nd Street F13 New York City, NY 10036 (212) 642-4900	Intl. Standards Org. 1 Rue Varembe C-56 CH1211 GENEVE 20 Sw. 41-22-749-0111	Soc. Automotive Eng's 400 Commonwealth Drive Warrendale, PA 15096 (412) 776-4841
Am. Soc. Test & Mat 1916 Race Street Philadelphia, PA 19103 (215) 299-5400	MIL Spec Order Desk 700 Robbins Av B4-D Philadelphia, PA 19111 (215) 697-2179	Soc. Motpic & TV Eng 595 West Hartsdale Ave White Plains, NY 10607 (914) 761-1100
Am. Radio Relay League 225 Main Street Newington, CT 06111 (203) 666-1541	Nat. As. Broadcasters 1771 N Street NW Washington, DC 20036 (202) 429-5300	Standards Eng. Soc. P.O. Box 2307 Dayton, OH 45401 (513) 223-2410
As. Computing Mach. 11 West 42nd Street F3 New York City, NY 10036 (212) 869-7440	Nat. Elec. Manuf. As. 2101 L Street NW Washington, DC 20037 (202) 457-8400	Underwriters Labs 333 Pflingsten Road Northbrook, IL 60062 (708) 272-8800
Compliance Engineering 629 Massachusetts Ave. Boxborough, MA 01719 (508) 264-4208	Nat. Fire Prot. As. Box 9101 Quincy, MA 02269 (617) 770-3000	US Govt Bookstore 720 North Main Street Pueblo, CO 81003 (719) 544-3142
Electronic Ind. As. 2001 Pennsylvania Ave NW Washington, DC 20006 (202) 457-4900	NIST (US Bureau Stds) ADMIN E-128 Gaithersburg, MD 20899 (301) 975-3058	----- Fed. Information Cen. (800) 359-3997 -----
IEEE Electronic Eng. 345 East 47th Street New York City, NY 10017 (212) 705-7900	Nat. Standards Assoc. 1200 Quince Orchard Blvd. Gaithersburg, MD 20878 (800) 638-8094	

video camera, digital audio, and new broadcast satellite chips. And from *Silcon Systems*, a pair of newer data books on *Communications Products* and *Storage Products* chips.

Free user samples of the TPIC2801 intelligent power drivers and a nice Application Report are available from *Texas Instruments*. This one is particularly useful for automotive and solenoid driver applications.

And through *Aremco*, a *Materials Catalog M12* which includes a wide variety of high temperature ceramic materials, including machinable and pourable versions.

Trade Winners now has a US phone and address. This Hong Kong answer to *Computer Shopper* gives you direct wholesale access to far eastern computer and electronic sources.

The monthly *EPRI Journal* is full of power ideas, ranging from solar to energy conversion to cold fusion, to cogeneration. It is free to utilities or anyone associated with the media, but \$29 per year otherwise. *EPRI* also has lots of videos and reports.

The *Alternate Energy Sourcebook* is a combination catalog and resource

file offered at a refundable \$14 from *Real Goods*. On their catalog side, you will find such goodies as solar panels, pumps, DC lights, and such. On the resource side are tech articles by Amory Lovins and directories to electric vehicle clubs.

How to Automate your Home is a new self-published manual by David Gaddis and offered through *Home Automation USA*. Well done.

I have newly revised and reprinted the second edition to my *Incredible Secret Money Machine*, and now have autographed copies in stock for you. And for those of you interested in Display PostScript, I've now posted a freeware *GhostScript* clone to my *GENie* PSRT board. Included are special Ghostscript fonts and the full source code. You'll also find *Hardware Hacker* and *Blatant Opportunist* preprints here, along with bunches of goodies not available elsewhere.

Our usual reminder here that most of the products and services mentioned appear either in the *Names and Numbers* appendix or the *Association Resources* sidebar.

Let's hear from you. ♦

Don Lancaster's

Hardware Hacker

January, 1992

Effective shielding ideas
Computer monitor basics
VGA Adaptor for Mac LC
Recurrent flyback sweeps
GPS Navigation Resources

It seems I did miss an obvious source in our recent *Tesla and High Energy Resources* sidebar. This is the *Tesla Society* up in Colorado, who do run a great museum and now offer annual Tesla and non-traditional energy conferences. Their *High Energy Enterprises* division has lots of books and videotapes.

These range the gamut from hard-to-find and genuinely useful research materials on down (*wayy... on down*) through bunches of "Boy-a-whole-flock-of-them-flew-over-that-time!" pseudoscience titles.

On the other hand, if you are into antigravity, the 1000 miles per gallon carburetors, Russian weather control conspiracies, *Reed* motors, all those pangalactic happy faces on Mars, or zero point scalar energy, these books and videos are definitely for you. This is *most* fascinating reading and watching, either way.

Actually, I'll freely admit that I firmly now believe in one trilateral conspiracy. That's the one involving the first, second, and third laws of thermodynamics. But that's just me. And if you want to prove me wrong, just show to me any simple and an independently verifiable experiment that anyone can reliably duplicate.

Some more info on wavelets: The *Wavelets* book offered by *Jones and Bartlett* is at long last in print. And a major new tutorial just came out in the October 1991 IEEE-SP *Signal Processing* magazine on pages 14-38.

Shields and Shielding

These have been popular topics lately on our helpline, so perhaps it is time to go over some fundamentals. You can *shield* something electronic either to keep objectionable signals from getting out or getting in. For instance, on any light dimmer, you might want to suppress the horrible AM radio interference caused by a triac suddenly turning on. On a low level audio circuit, you might want to prevent power line hum and noise from getting to you.

If you do know ahead of time that

you're going to have interfering noise or signals present, one very powerful technique is to change over to fully *balanced* circuits. These sense only the *differences* between their inputs, rather than any absolute values with respect to ground. Thus, any *common mode* interfering signals that bounce both inputs up and down together will automatically be rejected. Or at least suppressed.

Several fancy audio studios have even gone to totally balanced power lines to dramatically reduce their hum and noise problems.

There are usually two paths that interference can travel. One is with *radiated* energy, which can propagate directly through space to emit from or interact with your circuit. The other is *conducted* energy, which enters along your power connectors and input or output cables.

Since separate tricks are needed to deal with any radiated or conducted energy, step one is finding out *which* path is the one to deal with first.

The radiated energy interference will usually have two components. These are that "E" or *electric* field, which largely concerns itself with the induced *voltages*; plus that "H" or *magnetic* field, which creates induced *currents*. Once again, you have to know *which* field component you are

going to suppress.

Any old conductor should usually block an E field. One obvious hacker choice that works well are boxes built up out of double sided printed circuit board. See figure one.

But there are gotchas. At lower frequencies, there is the lack of a well developed *skin effect*, which causes an E field to penetrate *deeper* into a conductor. Thus, *thicker* shields are needed to suppress *lower* frequencies. Say 20 mils for an AM broadcast band use or 80 mils for the high ultrasonic frequencies.

A shield can also act as a shorted turn to any nearby inductor, possibly lowering the Q and detuning. A slot or other continuity break can sometimes help this problem.

While some small shield holes are often tolerable, any poor contacts are definitely not. A continuous solder bead or else lots and lots of individual screws may be needed for really high shielding effectiveness.

It's very important that unintended currents don't ever run through any shields. Unwanted signal drops can often end up in *series* with your input signals, making things much worse rather than better. Which is also why you should keep all your digital and analog grounds separate.

The H fields can be blocked by use

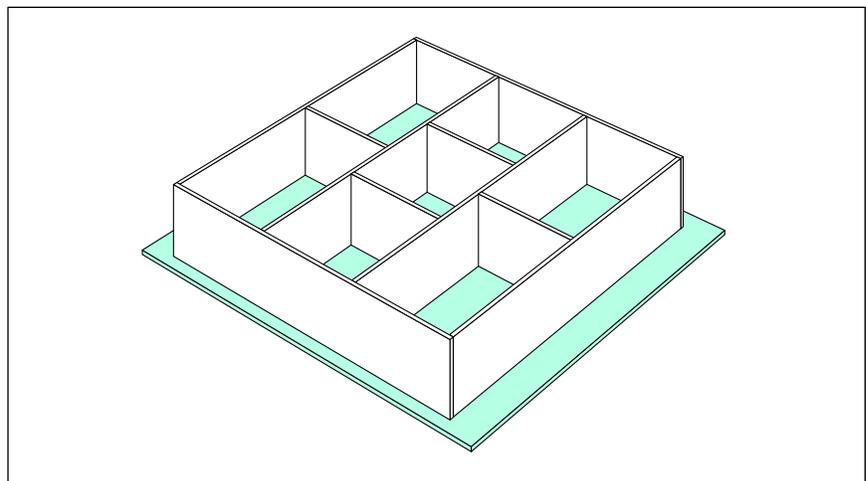


Fig. 1 – SIMPLE E-FIELD SHIELDS for radio frequency hacker projects are easily built up from pieces of double-sided printed circuit board stock.

of any strongly magnetic materials. These materials are said to possess a very high *permeability*. The simplest magnetic shield is any piece of scrap sheet steel from the air conditioning shop or trailer hitch works. But things get messy in a hurry if you need lots of magnetic attenuation.

Those special and fancy shielding materials are optimum only in certain thicknesses and over a specific frequency range. Worse yet, some of these cannot be cut or drilled without a complex reannealing process. And too strong of a magnetic field could saturate a shield, making it useless.

To be effective, a magnetic shield should completely surround the volume it is protecting.

A good free booklet on all of the fundamentals of magnetic shielding is available from *Amuneal*, while other sources of custom shield materials

now include *Advance Magnetics* and *Magnetic Shield Corp.*

Conducted interference can be best eliminated by some blocking filter. These filters should freely pass the signals of interest, but present a high series impedance and a low shunt impedance to all others. *Murata-Erie* is one good source.

The *ferrite bead* is a remarkably cheap and super effective interference suppressor. As figure two shows us, you simply hang these onto a wire or else run a turn or two through them. Ferrite beads act as a broadband high frequency lossy transformer. There are various materials and sizes.

Sources of ferrite beads include *Fair-Rite*, *FerriShield*, *Ferroxcube*, *Intermark*, and *Siemens*.

One very little known ferrite bead gotcha: Do not ever cast a ferrite bead in epoxy or otherwise constrain it so

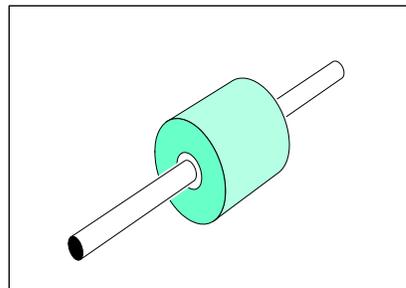


Fig. 2 – THOSE FERRITE BEAD interference suppressors are slipped onto any conductor and behave as lossy and broadband transformers.

it cannot move. The beads *must* be able to physically change their size slightly, or else the performance will sharply degrade.

Two trade journals that involve themselves with shields and shielding are *Electronics Test* and *Compliance Engineering*.

Some Monitor Fundamentals

We sure do get a lot of computer monitor and tv compatibility calls. Let's start off with the obvious: The performance and bandwidth of an ordinary tv or VCR using *composite* NTSC video is severely limited. That is why all the computer folks went to special RGB monitors in the first place. And that is why nearly all the computers are *totally incompatible* with ordinary television gear.

Yes, there now are all sorts of ways you can use your computer for real video editing or to record computer screens on a VCR. But note that there is *no way* I know of that you can record plain old 80 column text as composite video on your VCR. Or display it on any unmodified tv set. Especially in color. If you are going to put something out as broadcast video or record it on a VCR, it has to look like all the other stuff that you see on your cable channels. Which means a few big characters, rather than zillions of small ones. And far fewer lines of horizontal resolution.

How does a monitor work? Inside is a cathode ray "picture tube" with one or more guns that squirts lots of electrons at a phosphor screen. At any instant, *only one single dot* appears on the screen. That dot gets moved around by the scanning process, and will get brightened and dimmed by

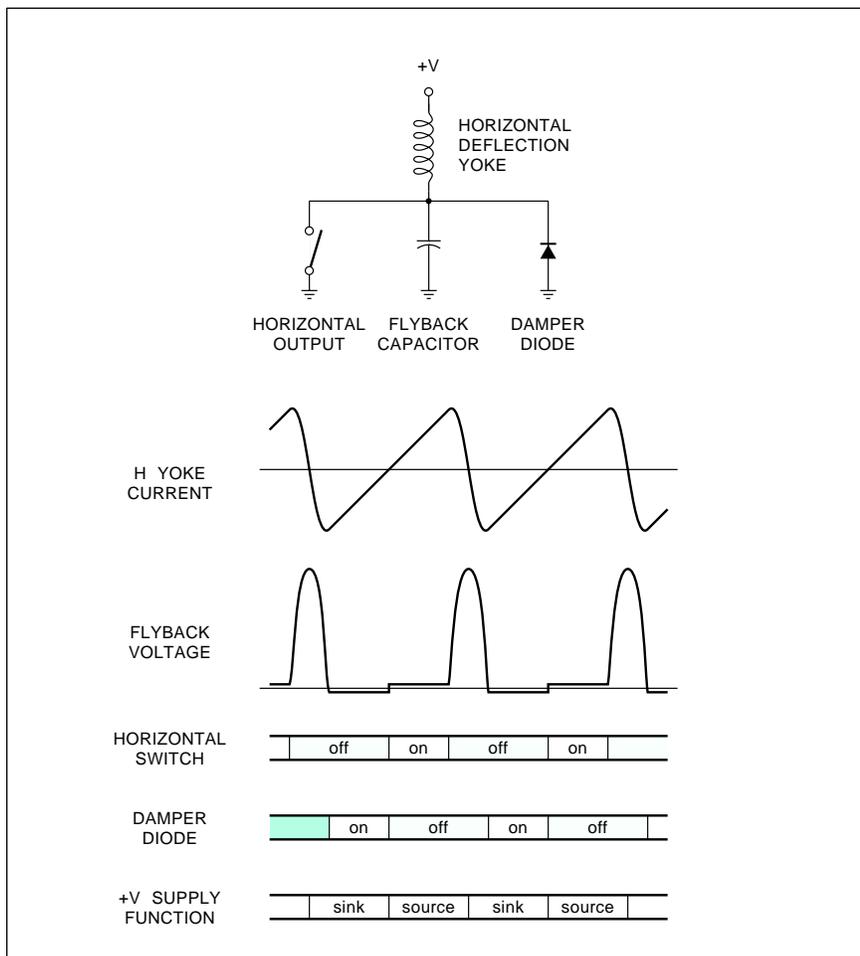


Fig. 3 – THE RECURRENT FLYBACK SWEEP on television sets and computer monitor displays is extremely energy efficient, but will only work over a VERY limited range of horizontal scan rates.

rapidly setting its intensity at a *video* modulation rate.

To build up the *illusion* of a full picture, that scanned dot is moved rapidly and *horizontally* from left to right and more slowly *vertically* from the top to bottom. The decay characteristics of the phosphors selected and your human persistence of vision combine to create the *illusion* of a total picture.

Television uses what is known as an *interlaced* scan. To build up a *frame*, the dot starts at the upper left and rapidly scans to the right and slowly on downward, painting every *second* scan line. When it gets to the bottom of this *field*, it goes back to the top and picks up what it missed, painting a second field. The normal field rate is usually 60 Hertz for black and white or 59.94 Hertz for color.

The NTSC (or the *Never The Same Color*) standard uses 512 lines per frame, or 262.5 lines per field. Which leads to standard horizontal scan rates of 15750 Hertz for black and white or 15735 Hertz for color use. These two numbers end up slightly different to get all the rest of those color magic numbers to properly drop in place.

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Interlaced scan is used by NTSC to minimize flicker. But *interlaced scan is totally unsuitable for data displays, especially small text!* The reason is that interlace only works if successive lines are more or less the same. This is clearly *not* the case between dot lines of finer text. Thus, most computer screens *demand* a *noninterlaced* display where each field is complete and identical.

Most computer monitors also will use a 59.94 or a 60 Hertz vertical scan rate. Get under this and you'll end up with too much flicker. If you try to lengthen the phosphor persistence you may end up with "comets" for traveling balls.

The horizontal scan rate is decided by how many horizontal lines you are using per field. As you *increase* the number of lines in a display, the *horizontal scan rate goes up*. Scan rates from 22 to 45 kilohertz are typical, with some exotic displays going much higher.

Now for the kicker: *Most monitors will only work over a VERY limited range of horizontal scan frequencies!*

Unless you go to some very fancy

multi-sync techniques.

Before you can use any monitor in any system, you must make sure the horizontal scan frequencies are compatible with your intended use!

Understanding Flyback Deflection

Why can't someone just build a monitor that accepts an ultra-wide range of horizontal scan frequencies and be done with it? The answer to this has much to do with both energy conservation and the way things have been done in the past.

A set of coils known as a *deflection yoke* normally goes on the neck of the display tube. These are plain old coils that will move your electron beam to wherever you want it to go.

Normally, the horizontal yoke is where all the action is, since it does things several hundred times faster than the vertical one.

Since several kilowatts or more of deflection power are involved in the horizontal deflection of a larger color display, sneaky tricks will have to be played to reuse and recycle all of the energy involved. These sneaky tricks go by the name of *recurrent flyback deflection*, and are shown to you in figure three.

The basic rule of any inductor is

that...

$$e = L \Delta i / \Delta t$$

Lets rearrange things a tad...

$$\Delta i / \Delta t = e / L$$

Now Δi is the change of current and Δt is the change of time, so $\Delta i / \Delta t$ will be a *linear current ramp* whose rate of change should equal your supply voltage divided by the inductance of your horizontal yoke.

Say that the switch in figure three is now open and has been that way for a long time. There is no current in the yoke, and no deflection. The spot will still be in the middle of the line.

Now, close the switch, but just for around *one-half* of the live scan time. What happens? We now apply a positive voltage to an inductor, and start building a linear current ramp. That current ramp in the deflection yoke creates one linearly increasing magnetic field, and the spot moves to the right.

When you get to the right side of the screen, you'll have bunches of energy stored in the horizontal yoke's magnetic field.

What are you going to do with it? If you just burn it up as heat, you'll end up with bad reliability and high

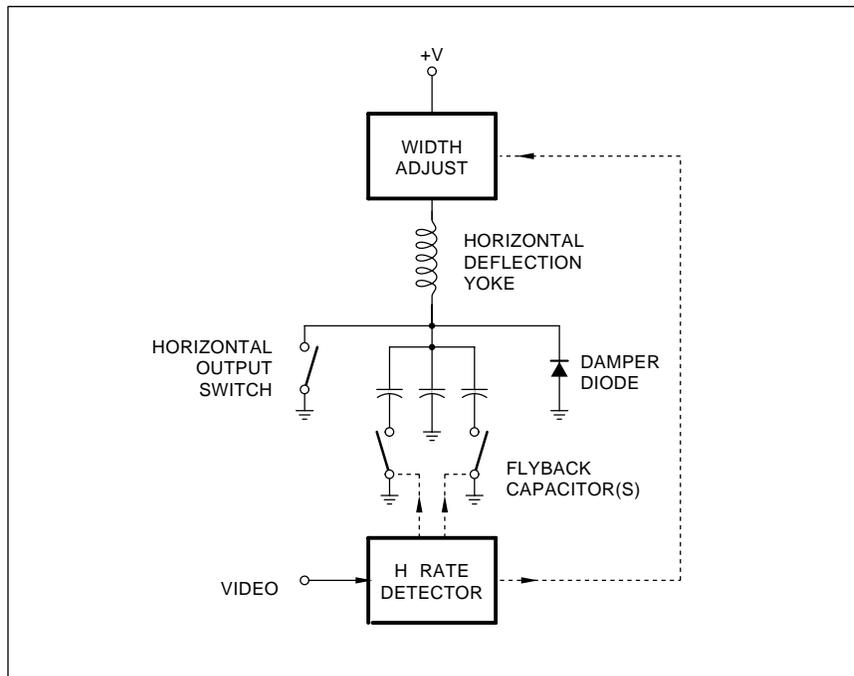


Fig. 4 – MULTI-SYNCING MONITORS change their sweep values to try and match an input horizontal scanning rate. But once selected, they still operate only over a very limited frequency range.

power consumption. Besides needing *far* tougher electronics. Instead, let's work smarter instead of harder.

Open your switch. Your equivalent circuit now consists of a yoke coil in series with the *flyback* capacitor. A standard and high Q series resonant circuit. But one that started out with zero volts on your capacitor and a strong current through the coil.

At this time, all of the energy is in the coil and none is in the capacitor. Let the circuit resonate for a while, exactly like any other series resonant circuit. In one quarter of a cycle, the capacitor will be charged up to a large positive voltage, often in the 800-1200 volt range. At the peak, your current will be zero, and our inductor will be "empty" and field free.

You have now transferred all of the magnetic energy that was in the yoke into electrical energy stored in the flyback capacitor! And done so with very little loss.

Let the circuit continue to resonate. The current will *reverse*, and energy will start transferring back *into* the inductor. Note that the current is now going in the *opposite direction*.

Let the circuit resonance continue

until the capacitor gets to zero volts. You will now have placed all of the original magnetic energy right back into the deflection yoke, with one very important difference: Since the current is going in the opposite direction, you're now at the *maximum left* spot position, compared to the maximum right that you were half a resonance cycle ago. And, again, you have done this with very little loss of energy.

This process is known as a *flyback*, and the retrace interval is called the *flyback time*. The beam is turned off during the flyback time so the retrace is invisible.

Let the circuit resonance try and continue. The flyback capacitor will try and go negative, but at that time, a *dampener diode* will turn itself on. Your circuit now consists once again of a coil connected between the positive voltage and ground. It will once again start generating a positive current ramp. Only this time, it starts from a *negative* initial current. Thus, your sweep starts linearly moving from the left to the center. As you move on towards the center of your scan line, the yoke energy gets sent back *into*

the positive supply.

When you get to the center of the screen, you once again close your switch to repeat everything for the next cycle. The dampener diode shuts down just as soon as you cross center screen. Automatically.

Once again: Close your switch to move from center to right. Transfer the coil energy to a flyback capacitor. Resonate half a cycle and transfer the flyback capacitor energy back to the coil *inverting its sign* and putting you far left. Turn on the damping diode to move from left to center. And repeat the process once each scan line.

Several details I've omitted: That flyback pulse also gets sensed and routed to a current stepup transformer called a *flyback transformer*. The flyback transformer steals a minor part of the energy and uses it to create the high voltage dc supply that is needed by the display tube. Other windings can be used for blanking, horizontal phase comparison, and boosted supply voltages elsewhere in the tv or monitor. And games have to be placed to keep any uncentering dc bias out of the horizontal yoke. But regardless of these details, the basic concept of recycling your deflection energy remains.

At any preselected horizontal scan frequency, the flyback system works and works well. But if you try and change the scan rate by more than a few percent, the voltages, currents, and resonances quickly get out of hand. Thus, this very elegant, highly tested, and ultra conservative flyback scheme inherently works best only at *one* horizontal scan frequency.

And that is why you can't normally get a monitor that can accept any old horizontal rate.

Yes, there are multi-sync monitors. These usually work by measuring the intended input scan frequency and then switching in one or more flyback capacitors and adjusting the supply voltage accordingly. Our figure four shows one multisync scheme. Once switched, a multisync monitor is a narrowband system just like any other flyback-driven circuit.

The bottom line: A monitor only works at its intended horizontal scan rate. And at no other.

VGA For the Mac LC

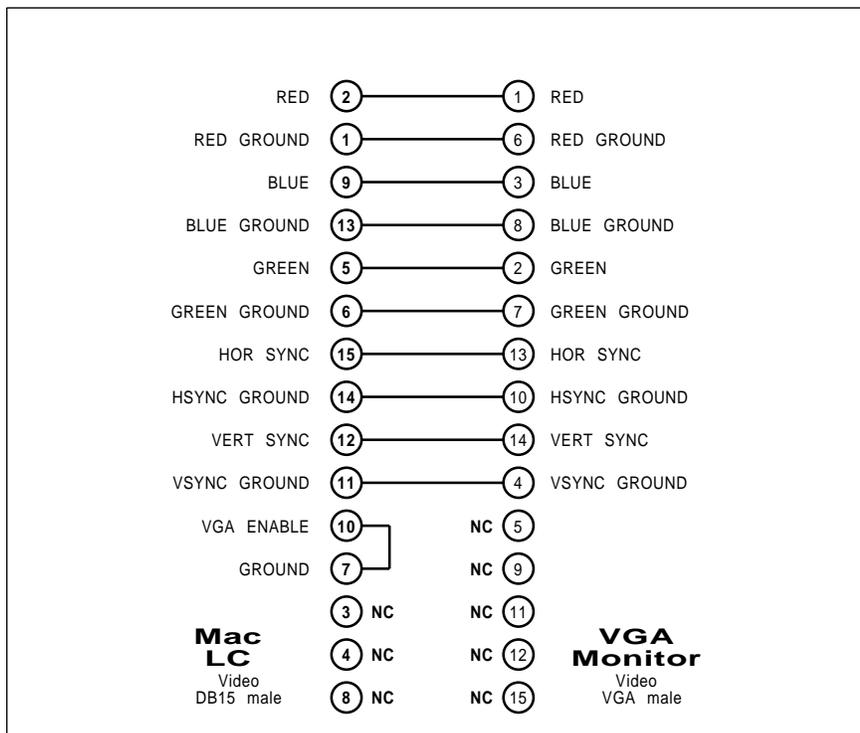


Fig. 5 – THE MACINTOSH LC definitely can NOT be used with a NTSC monitor. But this simple cable and jumpering lets you use it with most VGA color monitors. The pin7 to pin 10 jumper selects the VGA mode.

The Macintosh LC computer was designed for use with the Mac color monitors to the Mac color standards. Since these can be expensive, lots of hackers are often on the lookout for lower cost substitutes. But note that you definitely can *not* use a NTSC color monitor with these because of the higher scan rates on the LC.

And also do note that you should *never* buy a substitute monitor without making certain it works and is good enough for your uses.

Happily, there is a hidden "secret" provision on the Mac LC that lets you change your LC output so it is VGA compatible. Quality VGA monitors are often available much cheaper in far wider selections than are "real" Mac monitors.

The secret jumper that changes the LC scan rates for VGA compatibility is shown you in figure five.

GPS Nav Resources

From time to time we've looked at the *Navicube* concept right here in *Hardware Hacker*. The *Navicube* is a magic \$5 cube 3" on a side which always knows where it is and which way it is pointing. Several recent developments that should ultimately make the *Navicube* possible include low cost accelerometers, advances in new fiber optic gyros, and the ongoing GPS navigation system.

GPS is short for *Global Positioning Satellites*, a military navigation system that has recently seen several dramatic improvements in price, reliability, and availability. I've tried to gather together some GPS info for you as this month's resource sidebar.

The system consists of a flock of roving satellites, any five or six of which should be overhead at any given time. These satellites broadcast a series of low microwave frequency radio signals. By intercepting and comparing the signals from several overhead satellites, you can extract your current absolute position and do so to around a fifty foot accuracy. Your speed, acceleration, and current time could also get determined to surprisingly high accuracies. Within two inches per second even.

And by shifting to a *differential* scheme from any one known and fixed point, you can improve your accuracy to a fraction of an inch.

GPS NAVIGATION RESOURCES

Ashtech

390 Potrero Avenue
Sunnyvale, CA 94086
(800) 229-2400

Bancomm

6541 Via del Oro
San Jose, CA 95119
(408) 578-4161

GPS World

P.O. Box 10460
Eugene, OR 97440
(503) 343-1200

Magellan Systems Corp.

960 Overland Court
San Dimas, CA 91773
(818) 358-2363

Magnavox

2829 Maricopa Street
Torrance, CA 90503
(800) 421-5864

NASA Tech Briefs

41 East 42nd Street Ste. 921
New York City, NY 10017
(212) 490-3999

Rockwell Commercial GPS

P.O. Box 568842
Dallas, TX 75356
(214) 996-5863

Speleonics

P.O. Box 5283
Bloomington, IN 47407
(812) 339-7305

TI/GPS Products

PO Box 869305, M/S 8449
Plano, TX 75086
(214) 575-4057

Trimble Navigation

585 North Mary Avenue
Sunnyvale, CA 94086
(800) TRI-MBLE

Amazingly, the antennas needed are no big deal. They can easily fit inside a small shoebox. Unlike video satellites, the GPS antennas need a wide bandwidth, a narrow frequency bandwidth, plus the pseudorandom modulation which works acceptably well with lower signal-to-noise ratios. The antennas do require line-of-sight operation, so they have to be used outdoors, on a rooftop, or on the top of a vehicle or boat.

Since the reception electronics is incredibly complex, it is unlikely you would want to try and build up your own GPS receivers by using discrete components.

Thankfully, sophisticated chip sets are now becoming readily available from *Rockwell*, *Magellan*, and others. Their initial pricing is in the \$500 range. But it is reasonable to expect Japanese GPS chips within a year or two for under \$35. So now is the time to start on your GPS hacks.

Even today, the pricing is certainly within the range of, say, trucking firms or land surveyors.

The leading trade journal in this new field is called, of all things, *GPS World*. It is free to qualified subscribers. An interesting hacker newsletter that deals with navigation and comm of interest to cavers is Frank Reid's great *Speleonics*. Some other GPS info appears from time to time in *NASA Tech Briefs*. Several other sources of GPS gear include *Ashtech*,

Bancomm, *Texas Instruments*, and *Trimble Navigation*. Trimble has a nice GPS intro book available titled *GPS - A guide to the next utility*.

Let me know if you want any more specific info on the GPS frequencies, codings, and user protocols. I'll be happy to get into this further if there is enough interest.

New Tech Lit

From *Actel*, a new databook on *Field Programmable Gate Arrays*. And from *Mini-Circuits* a new *RF/IF Signal Processing Guide* on higher frequency mixers, splitters, amplifiers, transformers, and such. Their broadband amplifiers cost around a dollar or so each.

A free update on our Santa Claus machine technology is now titled an *Insiders Guide to Rapid Prototyping*, and is available from *Management Roundtable*. These folks also put on annual conferences.

A new quarterly hacker newsletter on lower cost vacuum projects and techniques is now available through *Steve Hansen*.

Free samples of *Liquisorb*, a low cost cornstarch colloidal absorbent, are available from *American Colloid Company*. Since these sample packets dramatically swell up in the presence of liquid water, one obvious use is as a low cost flood alarm where the expanding package actuates a switch of some sort. ♦

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